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ECONOMIC AND ENVIRONMENTAL IMPACTS OF USING MUNICIPAL SEWAGE EFFLUENT FOR AGRICULTURAL PRODUCTION IN OKLAHOMA

By

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CHAPTER I

INTRODUCTION

The Problem

Land application of municipal sewage effluent, a practice which dates back to 1872 in the United States, is a treatment alternative which is gaining in importance due to two factors: the necessity to dispose of sewage effluent in a proper manner, and the increasing demand for water, including irrigation water for agricultural purposes.

Municipal governments are faced with increasing institutional restrictions on conventional treatment and handling of sewage effluent. Federal and state environmental quality regulations encourage innovative and alternative (I&A) methods of sewage effluent treatment, such as land application. The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) set a goal of zero discharge of pollutants into navigable waters by 1985. This Act, along with the Clean Water Act of 1977 (PL 95-217), provides for construction cost-share grants for wastewater treatment facilities.

Under the Environmental Protection Agency (EPA) funding policy, I&A methods of treatment have had a comparative advantage in funding over conventional treatment processes in the percentage of cost borne by the federal government (85 percent federal - 15 percent local versus 75 percent federal - 25 percent local). Beginning October 1, 1984, funding for I&A methods was reduced to 75 percent federal - 25 percent local, and funding for conventional methods was reduced to 55 percent federal - 45 percent local.

Although funding for both categories decreased, I&A treatment processes such as land application still have a large comparative advantage over conventional treatment processes. On the state level, the Oklahoma State Department of Health (OSDH) recommends land application as the most effective method of wastewater treatment for most towns in Oklahoma.

Regulations regarding conventional treatment and disposal methods have become more stringent relative to I&A methods. Examples include: the increasing restrictions on issuance of National Pollution Discharge Eliminating System (NPDES) permits for disposal of pollutants into navigable waters and oceans, the eventual phase-out of the NPDES permits, termination of funding for conventional treatment processes beyond secondary levels by EPA under the Reagan administration, and requirements by EPA of applicants for construction cost-share grants to thoroughly justify rejecting land application in the facilities plan if land application is not included in the recommended plan.

Demand for water for virtually all purposes is increasing in the United States due to rising per capita income and increasing population (Bishop, et al.). This contrasts with a finite supply of water. The total volume of water in the U.S., in the form of groundwater, surface water, and precipitation, is more than adequate. However, these sources of water are not distributed evenly with respect to geographic area, population, or need, resulting in areas where water is in relatively short supply. The agricultural sector is the largest water user, primarily utilizing water for irrigation, and as such has the largest impact on water demand in the United States.

In many areas of Oklahoma, farmers depend on irrigation water as a sole or supplemental source of water for agricultural production during the summer growing season. Many of those farmers also face increasing economic scarcity, and in some cases physical scarcity, of conventional sources of irrigation water. Municipal sewage effluent can be utilized as a partial or total water source for crop or forage production, and may also provide some benefits as an additional supply of plant nutrients (nitrogen, phosphorus, and potassium) when used in a slow rate application system.

The costs of constructing, operating, and maintaining a land treatment facility are generally considered to be lower than corresponding costs of conventional wastewater treatment systems (Williams, Connor, and Libby). As municipal governments face increasing costs and limitations with conventional sewage effluent treatment and disposal methods, and as farmers are confronted with increasingly costly conventional irrigation water resources, the benefits of land application become more significant to both the farmer and the municipality.

Despite these factors conducive to the utilization of municipal sewage effluent in a land treatment system with agricultural production as a component, the full potential of municipal wastewaters is not being realized. Reluctance exists on the part of farmers to use sewage effluent in their crop- and forage-producing enterprises. An apparent reluctance by municipalities to adopt land application as a component in a municipal sewage treatment system exists as well; in the seven year period following the passage of PL 92-500 in 1972, less than 10 percent of all new systems have included land application (Jewell and Seabrook).

A factor which may contribute to economic underutilization of municipal sewage effluent is the conflict of objectives between the supplier and the user. The municipality's goal is to minimize the costs of the wastewater treatment system. Since storage lagoons represent a substantial cost, a municipality with a land application facility often will maximize its wastewater loading rate on the site while still providing an acceptable quality of effluent treatment. This goal is often reflected in the contractual agreement between the municipality and the farmer. Thus, the farmer is often obligated to take a fixed amount of effluent. The farmer's goal is profit maximization. Implicit in such a goal is efficient utilization of irrigation water and economic optimization of crop yields. The sewage effluent loading rate that he faces in such instances is higher than that which is optimal for crop or forage production. The producer may be required to irrigate a volume of wastewater which is detrimental to the crop or pasture, or to the land, unless he/she can spread the effluent over more acres than those which the city's consulting engineer designed into the system.

Another contributing factor may be inflexibility in the volume of sewage effluent supplied to the farmer. Often in the contractual agreement, the farmer is obligated to receive a constant volume of wastewater on the irrigation site. However, the demand for irrigation water for crops or forage is seasonal. Water use by crops in Oklahoma during the summer may be 0.3-0.4 in./day, while winter water usage may be less than 0.1 in./day (Schwab and Stiegler). The farmer considering using municipal sewage effluent as irrigation water may be reluctant to enter into an agreement with the municipality under a requirement to take a constant amount of water all twelve months of the year.

The costs of storage facilities for effluent, which are borne by the municipality, are another factor in wastewater underutilization, and they also underlie the previous two factors. Though largely defrayed by construction cost-share grants, municipalities put forth great effort to minimize the expense of storage lagoons in a land application system. This behavior tends to limit consideration of lowering the irrigation site loading rate since, given no change in the acreage to be irrigated, more storage would be needed.

Negative attitudes toward reuse of municipal sewage effluent on the part of municipalities, farmers, or communities may limit the extent to which sewage effluent can be utilized in crop or forage production. If a municipality's officials, or its consulting engineers, view land application in a perspective of disposal of wastes rather than one of reclamation of wastes, efficient wastewater reuse is less likely to be considered. Farmers may object to using effluent for irrigation water, fearing the possibility of pathogens, salts, or heavy metals which may be detrimental to the crop, the soil, or to animal or human health. The citizens of a given community may resist land application technology as a result of mistrust, misinformation, health concerns, individual value judgments, or concern over reduced real estate values.

Specific Problem

A major concern of this study is the impact of excess application of municipal sewage effluent, during part or all of a given period of time, on land producing crops, forage, or pasture. Applying municipal wastewater at times when plants cannot utilize the water contains negative consequences for plant growth, wastewater treatment effectiveness, pricing of wastewater as an irrigation source, and crop or forage selection for profit maximization.

At application rates which exceed the capacity of plant usage, the treatment effectiveness of irrigating with municipal effluent diminishes. Plants do not remove all of the nitrogen and phosphorus from the effluent. Higher loading rates of effluent increase the percolation rate through the soil profile. Absorption of chemicals contained in the effluent by soil particles decreases, and leaching of the constituents of the wastewater into the groundwater becomes more likely. If the loading rate is sufficiently high to saturate the soil, the resultant anaerobic conditions would reduce the effectiveness of removal of BOD and suspended solids; the likelihood of buildup of these constituents is enhanced.

Groundwater pollution is salient in its importance relative to surface water pollution. Groundwater generally mixes poorly and flows slowly, typically less than 1 ft./day. Consequently, the dispersion of a pollutant through groundwater is slow, and the pollutant is capable of being transported long distances in concentration over a long period of time. Because the capacity of dispersion in groundwater is low, a groundwater supply, once contaminated, tends to stay contaminated for a long time.

If, as stated earlier, the full potential of municipal sewage effluent irrigation for agricultural purposes is not being realized, then the price of the effluent as irrigation water should reflect a condition of nonoptimality. The causes of economic underutilization of municipal wastewater, whether inflexibility of wastewater supply, conflicting goals of the municipality and the farmer, wastewater storage costs, negative attitudes toward wastewater irrigation, any combination of these factors, or some other factor, would manifest themselves in a low or even zero price charged to the farmer for the use of the sewage effluent in crop or forage irrigation. The extent of the impact of a given factor on effluent pricing depends upon said factor's impact on characteristics underlying supply and demand of municipal sewage effluent for reuse (Young, 1982). Under conditions which encourage application of municipal effluent at rates in excess of what can be efficiently utilized by agricultural plants, effluent as irrigation water will be undervalued relative to a situation where wastewater is used efficiently in agricultural production.

The cropping mix and the irrigation schedule are affected by high wastewater application rates. A constant, inflexible application schedule does not complement the seasonal water demand of crops or forage. The opportunity for water surplus or shortage during certain periods exists as a result. Such loading rate inflexibility may cause the farmer to irrigate in winter months, when crops cannot benefit from the water, and to irrigate conservatively in the summer months to make the water last through the growing season. Crops which are of lesser economic value but which use or tolerate large volumes of water may be selected for production to maintain system effectiveness and workability of the soil. An example of such crop and land use is found in Wells, Sweazy, and Whetstone.

Satisfaction of only the municipality's goal of cost minimization tends to encourage high, inflexible application rates of sewage effluent on the site. The potential of utilizing the effluent in the most efficient manner diminishes when the loading rate exceeds plant intake capacity, and certain effluent treatment problems increase in significance. Demand by farmers for effluent as irrigation water is decreased, distorting the relationship, as reflected by the price of the effluent, between the resource (effluent) and its use in producing the product (crops or forage). If the value of the marginal product of the effluent differs from the effluent price, then a more efficient combination of municipal sewage effluent and other inputs of agricultural production exists for a given production enterprise.

Objectives and Hypothesis of Study

The general objective of this thesis is to analyze the treatment method of land application of municipal sewage effluent in terms of economic impacts on Oklahoma farmers and municipalities and environmental consequences on Oklahoma communities and farms. Specific objectives are to:

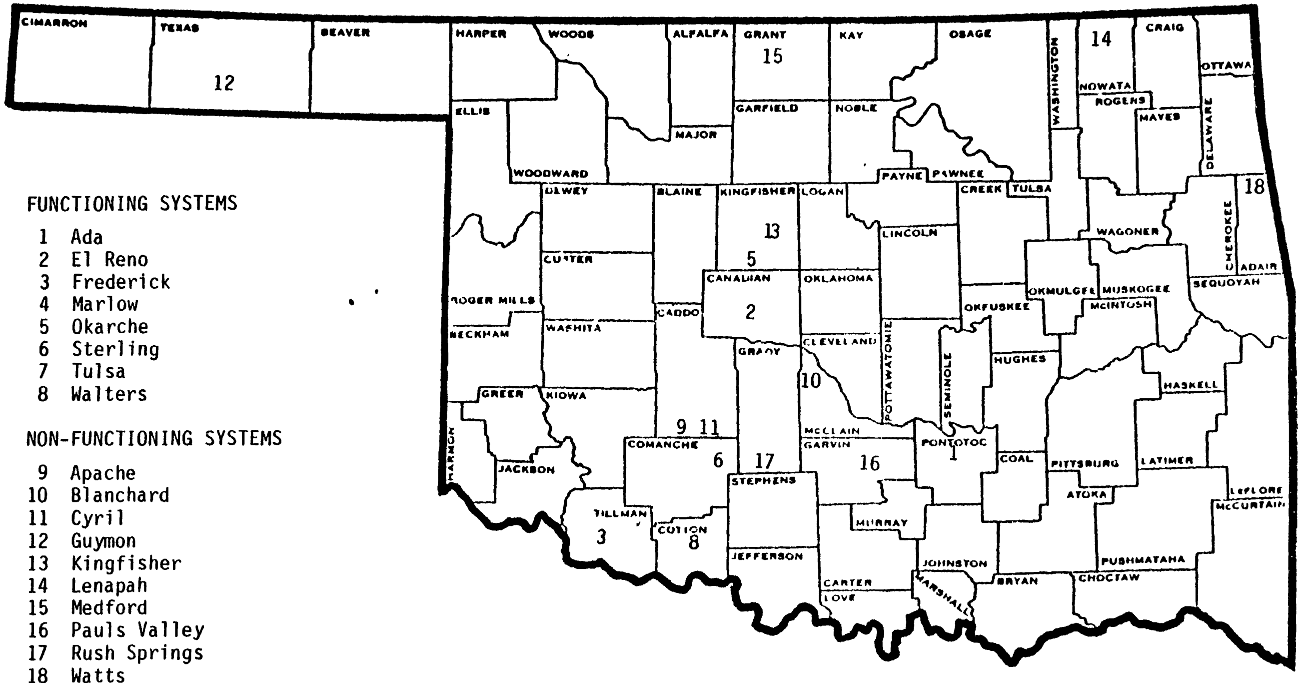
1. examine economic and environmental impacts of the land application method of handling municipal sewage effluent and,
2. analyze the economics of land application of municipal sewage effluent in a crop or pasture irrigation system designed to increase agricultural production while providing acceptable levels of treatment of the effluent.

The hypothesis of this study is: municipal sewage effluent can be used more efficiently and without significant adverse environmental impact in Oklahoma land application treatment systems by emphasizing the goal of optimal agricultural production and by pricing the effluent according to its value in agricultural production. Such increased efficiency will benefit the farmer in the form of increased net revenue from his/her operation and the municipality in the form of increased demand for effluent by farmers as a group. The primary difference between the hypothesis and current practice is the implied consequences in the hypothesis of reduced application rate of sewage effluent and increased acreage of irrigation.

Area of Study

The data needs of the study are satisfied in part by collecting information on completed land application systems in Oklahoma communities. The locations of the communities with land treatment systems in Oklahoma are shown in Figure 1. The key indicates the appropriate system status (functioning or non-functioning as of July 1984) for each community.

Only communities with slow rate land application systems which were complete at the time of the survey were personally interviewed. The remaining communities were interviewed by telephone. Most of the sample communities are located in southern and southwestern Oklahoma, which are regions with high evapotranspiration rates; the remaining municipalities are located in central and northeastern Oklahoma.



FUNCTIONING SYSTEMS

1 Ada
2 El Reno
3 Frederick
4 Marlow
5 Okarche
6 Sterling
7 Tulsa
8 Walters

NON-FUNCTIONING SYSTEMS

9 Apache
10 Blanchard
11 Cyril
12 Guymon
13 Kingfisher
14 Lenapah
15 Medford
16 Pauls Valley
17 Rush Springs
18 Watts

Figure 1. Locations of Municipal Sewage Effluent Land Application Systems in Study Area

Organization of Thesis

Chapter II contains a review of pertinent literature concerning land application of municipal sewage effluent. The methodology used to analyze the issues is presented in Chapter III. The survey technique and the linear programming model are explained. The results of surveys of municipal officials and farmers involved with land application systems in the study area are presented in Chapter IV. The results of the empirical model are presented in Chapter V. The summary of the study, limitations of the study, and suggestions for further research are presented in Chapter VI.

CHAPTER II

LITERATURE REVIEW

Land application of sewage effluent is a treatment process that has been practiced for many years. Wastewater irrigation with crop production as a component has been used in San Antonio, Texas since 1900 and in Lubbock, Texas since 1925; sewage irrigation was practiced in Augusta, Maine in 1872, in Cheyenne, Wyoming in 1881, and in Los Angeles, California in 1883 (Christensen; Wells, Sweazy, and Whetstone).

Jewell and Seabrook investigated the history of land application to gain insights into the reluctance to include land application in municipal sewage treatment facilities. The state of technology in waste treatment in different periods of time was examined, as well as the attitudes of officials and engineers.

A study by Bishop, et al. at Utah State University examined social, economic, environmental, technical and legal aspects of various forms of water reuse such as industrial recycle, land application and other forms of sequential reuse, and irrigation return flow. A framework within which water reuse policies would be formulated on several levels was developed. The Wasatch Front area in north central Utah was analyzed from the standpoint of economic efficiency. Supply functions for water resources in the area were developed from mathematical programming models of local hydrology and cost structures; demand functions for water resources were derived from empirical studies and mathematical programming models.

Kardos reported on a land application study conducted at Pennsylvania State University. Initiated in 1963, the study focused on application of the sewage effluent from both the University and the town of State College on agricultural and forest land. The effectiveness of removal of plant nutrients, bacteria, detergent residues, and mineral salts from the effluent was examined, as was the impact on crop and forest growth and groundwater and soil water quality. Application of sewage effluent increased crop yields over those of the control plot, but wastewater irrigation retarded growth in some species of trees. Removal of phosphorus, nitrogen, bacteria, and detergent residues from the effluent was highly efficient while mineral salt removal was somewhat less efficient. The quality of both the groundwater and soil water was improved. The author stressed that the success of the land application method was contingent upon maintenance of certain desirable aspects of soil condition such as adequate infiltration and percolation and a high exchange capacity.

A study by Williams, Connor, and Libby at Michigan State University examined the experience of six small rural communities in Michigan with land application treatment systems. The institutional, physical, financial, and agricultural characteristics of the various land treatment systems were studied. The operation costs of the land treatment facilities and those of four conventional treatment facilities in communities of comparable size were subdivided into accounts; a comparative cost analysis and a linear regression analysis of the accounts were made. The construction costs of all facilities also were analyzed. Operation costs were found to be lower for land application treatment systems than for their conventional counterparts; construction costs were also lower for land application in all communities but one.

Walker, in an EPA publication, recounted the history of the municipal wastewater treatment facility in Muskegon County, Michigan with respect to the land application/agricultural production component of the works. The conditions which prompted the inclusion of land treatment in the works, the costs of constructing the systems, the design of the system, the operation and management of the system, and the performance and cost reductions of the facility with the land application system were discussed.

A report by Christensen, et al. examined the technical, legal, and institutional components of land application in Michigan. Land acquisition options and their impacts on farmers' goals (income generation, wealth accumulation, firm growth, autonomy in decision making, and a sense of community participation) were discussed. The experiences of several Michigan communities with municipal land application treatment systems were reported and analyzed. The legal environment of farmers, municipalities, and Michigan communities in general was discussed.

In 1976, Webb and Badger analyzed the operation of a land treatment site with an agricultural production component in Pauls Valley, Oklahoma. Efficiency of operation of the treatment system was examined within a multiobjective framework including both the municipality's goal of disposal of all effluent in a safe manner and the farm manager's goal of maximizing agricultural production. System performance was measured by a water balance schedule for a twelve month period. For the year analyzed, the volume of wastewater applied was found to exceed normal application volume due to lack of holding pond capacity, and application timing was determined to be non-optimal as a result. The authors concluded that system efficiency from an economic and environmental standpoint would be improved by expanding effluent storage capacity and, in general, that proper management of the treatment system is essential for the full benefits of a land treatment/agricultural production system to materialize.

Christensen, in a 1982 USDA Economic Research Service publication, examined the long-term experiences of eight communities with land application treatment systems. The study analyzed the development of the systems, agreements between farmers and municipalities, and factors (social, site-specific, political, and economic) influencing system development over time. A comparison of the communities and of the systems was made. Options for land acquisition and system management and their impacts on farmers and the communities were discussed.

Sullivan, Cohn, and Baxter, in an EPA publication, reported the results of a 1972 American Public Works Association nationwide on-site field survey of approximately 100 land treatment facilities, as well as surveys of officials of land application treatment facilities, health and water pollution regulations at the state level, and experiences with land application in several countries. Several general and site-specific factors influencing adoption and implementation of land application technology were evaluated. Conclusions and recommendations were drawn from the survey.

EPA has published many bulletins on various aspects of land application treatment methods, including guidelines for systems, cost information on land application systems, evaluation of works using land application, and citizen handbooks disseminating information on land application and other I&A methods to communities.

The Oklahoma State Department of Health has published guidelines for designing municipal waste treatment systems in Oklahoma employing land application of sewage effluent. A framework was constructed within which design engineers can formulate system objectives, evaluate the effluent, plan the facility, and assess the environmental impact of the facility.

Young, in a 1982 article, outlined economic aspects of municipal sewage effluent reuse. Characteristics of wastewater application underlying supply of and demand for effluent for the purpose of reuse were discussed; said characteristics included volume and quality of the wastewater, availability and price of alternative water sources, government policies and programs, available reuse options, and public attitudes toward effluent reuse. A priori analyses of the impacts of the aforementioned characteristics on the wastewater reuse supply and demand curves were made.

A five year study by Cabbiness and Badger at Oklahoma State University estimated the potential fertilizer value of municipal sewage effluent. The nutrients supplied by the effluent from Pauls Valley, Oklahoma were evaluated in the forms of anhydrous ammonia, ammonium nitrate, superphosphate, and potash. The nutrient value per acre of the effluent as applied to various forage crops was calculated. No attempt was made to evaluate the value of the water component of the wastewater.

Wells, Sweazy, and Whetstone examined the value of municipal sewage effluent as a water resource. They argued that, despite the nutrients present, wastewater is worth less than conventional irrigation water because the sewage effluent is supplied at a constant rate while demand for irrigation water is variable, depending on temperature, wind, and other conditions affecting soil moisture.

Several studies have indicated that sewage effluent has been used in a suboptimum manner. Christensen's study showed that between 20 and 60 percent of the available effluent was applied to the land in the communities studied, and the suggestion was made that municipalities were not charging farmers for the full value of the effluent, being more concerned with treating as much effluent as possible. Wells, Sweazy, and Whetstone reported that as the volume of wastewater produced by the city of Lubbock, Texas increased over time, the farmer who owned the rights to the effluent could not increase his farming operation at a similar rate. This caused part of his land to be utilized only as a dumping site and a significant portion of his acreage to be devoted to forage crops which utilize high volumes of water but are not necessarily high profit crops.

A study by Cabbiness and Badger analyzed the impacts of land application of municipal sewage effluent previously returned to the North Canadian River basin on farmers holding water rights downstream. Groundwater to surface water transfers and surface water to surface water transfers were examined. Farmers were surveyed along the North Canadian River with respect to attitudes toward using municipal sewage effluent as their source of irrigation water. The study showed that if 100 percent of the wastewater in the study area was applied to land, no water would be available to downstream water rights holders in certain seasons.

Carlson and Young, in a study on factors affecting the adoption of land treatment of municipal sewage effluent, analyzed the effect of quality of effluent on demand for the land application treatment option. Data were collected on 125 U.S. cities, and both log linear and nonlinear demand curves for land application were derived as well as elasticities of demand for the various factors. Profit maximization was assumed. All variables had the expected signs. Factors which were determined to have a significant impact on adoption or non-adoption of land application were: 1) the local cost share on construction grants, 2) the price of wastewater for agricultural irrigation, 3) required degree of treatment, 4) capital costs for nonland treatment options, 5) rainfall, 6) volume of stream flow, and 7) daily volume of effluent. The price of land was deemed to be insignificant. The authors concluded that the municipalities in the study responded to economic incentives (construction grant share, value of irrigation water, stream discharge regulations, required treatment level, and prices for labor and capital) when selecting sewage effluent treatment technologies for their wastewater systems.

Baker analyzed the costs of secondary wastewater treatment alternatives. Construction costs and operating costs for land application facilities and several conventional treatment options were identified. Effectiveness of the treatment alternatives was measured. Land application was determined to be cost-effective relative to conventional treatment methods in many instances where advanced wastewater treatment is required. However, variables such as distance to application site, mode of land acquisition, and other site-specific considerations may make conventional treatment alternatives more cost-effective.

Young (1976) developed a simulation model, named the Cost of Land Application of Wastewater (CLAW) model, to estimate costs of land application systems under varying structural conditions. Cost estimates for six land application methods were derived. Young (1978) used the CLAW model to compare the cost effectiveness of land application with that of conventional wastewater treatment. Factors affecting the cost effectiveness of wastewater treatment facilities, with land application facilities highlighted, were examined. Crop selection in a land application/agricultural production system was found to have the most significant impact on cost effectiveness; other factors with significant impact were buffer zones, chlorination, and application rate.

Haith and Chapman developed a model to evaluate the cost-effectiveness of waste treatment management options to plan a combination of options that meets the Best Practicable Waste Treatment Technology (BPWTT) requirement for Publicly Owned Treatment Works (POTW) which discharge into navigable waters, as stated in PL 92-500. The model is a nonlinear total cost minimization model with decision variables being irrigation area (A), wastewater treated by the ith process (Q_i), and wastewater flows (W). The model is intended for use in the preliminary planning stage of cost-effectiveness analysis, to screen various treatment alternatives and combinations thereof. According to the authors, the practical application of the model is evaluation of wastewater treatment plans (i.e., given combinations of treatment options) by computing plan costs and determining whether the plan meets surface water and ground water quality standards. Analysis of treatment options for a hypothetical municipality was made via simulation.

Seitz and Swanson formulated and analyzed a cost minimization model for two waste treatment methods: land application with crop production as a component, and an alternative method. The total cost function was differentiated, and the first-order conditions were examined. The optimal rate of waste to be applied to land was determined to be dependent upon all variables and functions in the system, including the marginal cost of the alternative method of treatment. A simulation analysis for reclamation of strip-mined land with sewage sludge was made.

Ladd and Martin analyzed the impact of product characteristics on product price and demand for the product as an input. A neoclassical firm model and duals of linear programming blending models were used. The themes developed were used to evaluate corn grades but are also applicable to characteristics of sewage effluent and their impact on effluent price when effluent is sold as irrigation water.

The review of literature yielded a variety of perspectives from which to view land application of municipal sewage effluent. However, none of the sources, except the Webb and Badger report, emphasize utilization of municipal wastewaters in a perspective of multiobjective optimization, or the satisfaction of the goals of each party with respect to the goal of the other party. The hypothesis of this study and the tools of analysis toward the hypothesis differ significantly from the Webb and Badger study. Also, the review of literature failed to find any studies which attempted to monetarily evaluate municipal sewage effluent as a source of irrigation water for agricultural production. These issues are addressed in this study.

CHAPTER III

METHODOLOGY

The methodology involves the construction of a linear programming model for a land application treatment system in Oklahoma which includes production of crops or forage. Basic data and parameters of the model were obtained from surveys of farmers and municipal officials, land treatment system design manuals, and Oklahoma State University Enterprise Budgets. Model assumptions also affect the parameters. Analysis of the output of the model will be made in Chapter V.

Surveys

Survey questionnaires were prepared to interview farmers in the study area using irrigation in their crop and/or forage production enterprises. Municipal officials who have EPA approved land application systems for sewage effluent also were interviewed. Copies of the survey forms are in Appendix A. Personal interviews with survey area farmers and municipal officials were conducted during June and July, 1984.

Selection of municipalities for participation in the survey was based on information obtained from the Oklahoma State Department of Health on municipal sewage treatment projects in Oklahoma with EPA funding. The criteria for selection were that a community system had to have a land application component and that the treatment system was complete or near completion.

Farmers were questioned on their irrigation operations, specifically: which crops or pastures were irrigated, how many acres were irrigated, how much water was used, and the effectiveness of irrigation with respect to crop yields. Farmers were also questioned on the organization level of the farm business and the percentage of family income provided by the farm. Details of the agreement between the farmer and the municipality, including the volume of effluent taken and the length of the agreement, were obtained. Farmers were questioned on adjustments made in their farming operations if the effluent was not available when needed, and on any problems experienced with the application system. Recommendations to other farmers considering irrigation with municipal sewage effluent were sought.

Municipal officials were questioned on the size of their city's sewage treatment system, the construction grant awarded to their city by EPA for the land treatment component, what alternatives (if any) to land application were considered, and the nature of the agreement between the city and the landowner for use of the application site. The officials were asked how their land treatment systems performed. Information on costs of land treatment versus costs of alternative treatment methods was obtained. Questions were asked on how the municipal officials viewed the land application method compared to other treatment methods. Recommendations for other municipalities considering land application of their wastewater were sought.

To supplement the personal survey, telephone interviews were conducted with municipal officials in communities where land application systems were being planned or constructed. Officials were questioned about the planned operation of the system with regard to system size and configuration, crop or forage selection for the application site, and the agreement between city and landowner. City officials were also asked if any alternatives to land application were considered.

Basic Data

Most of the matrix coefficients came from the Oklahoma State University Enterprise Budgets. The budgets provided information on requirements for labor, nitrogen, phosphorus, water, operating capital, and other inputs into crop and forage production enterprises, as well as information on productivity of alternative enterprises. Copies of the enterprise budgets used in this study are located in Appendix B.

The coefficients used for nitrogen and phosphorus concentrations in municipal sewage effluent were average city effluent figures for Oklahoma municipalities (Schwab and Stiegler). Information on dry matter content of forages and daily minimum dry matter consumption by beef cattle came from NRC tables in Animal Feeding and Nutrition. Dry matter data were used to convert animal unit months (AUM) of forage to units for which selling prices were obtainable.

Information on the sewage effluent system design data was obtained from Process Design Manual for Land Treatment of Municipal Wastewater (published jointly by EPA, USDA, and the U.S. Army Corps of Engineers) and the Oklahoma State Department of Health's Design Guidelines for Land Application of Municipal Wastewater. Included in the data are annual rates of precipitation, evapotranspiration rates, operation and management (O&M) costs, and water usage.

The Linear Programming Model

The empirical model used for analyzing economic impacts of land application of municipal wastewater was a polyperiod linear programming model. A representative farm budgeting approach was used. The model considers 240 application periods and 20 production periods, covering a span of 20 years. The scope of the model corresponds with the minimum time period required by EPA for lease agreements between a municipality and a farmer or landowner.

A discussion of the modeling process follows. Assumptions made for the models are presented first. The basic mathematical concepts underlying linear programming are presented second. The structure of the models, with particular reference to the technical constraints of the models, is presented last.

Assumptions

Two models were used to consider the economic impacts of irrigation of cropland with municipal sewage effluent. The irrigation model is that of a farmer who is a profit maximizer granting the municipality easement to his/her land for application of sewage effluent in a treatment system with agricultural production as a component. The municipal government, with EPA cost sharing, provides the center pivot sprayer irrigation equipment and bears the costs of storage lagoons; the city also bears all O&M costs. The model is constrained to either apply the municipal sewage effluent to the land or store it; all effluent supplied by the city in a given month must be accounted for. Effluent placed in storage in a given period is available for application in future periods. The dryland model is also that of a farmer who is maximizing profit from his/her production enterprises. Agricultural production in this situation takes place under dryland conditions. The producer has full control and responsibility over his/her production activities; there is no partnership with a municipality or any other party.

A representative farm approach was used in the modeling process to make the results of the model optimizations as realistic to Oklahoma farm producers as possible. The acreage of both farms was set at 240 acres, subdivided into three tracts of 80 acres. All of the 240 acres of the irrigation model can be irrigated with municipal sewage effluent. The farmer has 2,500 hours of labor in each production period. Initial operating capital of $15,000 was available to the farmer in year 1. The farmer possessed no initial stocks of nitrogen or phosphorus. Additional units of labor, nitrogen, phosphorus, and operating capital may be purchased by the farmer in both models.

Fixed amounts of nitrogen and phosphorus are applied as commercial fertilizer in the irrigation model. Such an assumption is made to insure that seasonal peak demands for plant nutrients are met, since production periods are in years and effluent application periods are in months. For each acre, 60 pounds of phosphorus are applied to alfalfa, 100 pounds of nitrogen and 20 pounds of phosphorus are applied to bermuda grass, 35 pounds of nitrogen are applied to grain sorghum, and 30 pounds of nitrogen and 30 pounds of phosphorus are applied to wheat. Variable and fixed costs of fertilizer and application are figured into the production costs. Crop nutrient requirements above what is met by this fertilization are met by either the nutrients in sewage effluent or the purchase of additional fertilizer. Not all plant nutrients in the effluent are available for crop use due to soil fixation and leaching; 50 percent availability in a given year is assumed.

The cropping pattern is identical for both the irrigated and dryland models. Alfalfa and grain sorghum are rotated on tract A; alfalfa is raised five years and grain sorghum is raised the sixth year. Bermuda grass is grown on tract B all 20 years as a permanent pasture. Wheat is produced on tract C for all 20 years; such constant production, while presenting increased difficulty in weed control and in maintaining the productivity level, is a common practice by Oklahoma wheat producers. Production on tracts A and B start in spring of year 1, while wheat production on tract C begins in July of year 1.

Variation in the types and sizes of farm machinery used in the OSU Enterprise Budgets necessitated an assumption of a fixed set of machines and implements for both the irrigated and dryland models. The purpose was to streamline the number of machines used and remove certain errors in the machinery requirements section of the OSU Enterprise Budgets. The variable and fixed machinery costs were recalculated according to the machinery available in each model.

Harvesting assumptions were based on the enterprise budgets used. Alfalfa production activities used equipment owned by the farmer; all other production activities used custom harvesting. Since bermuda grass pasture budgets were converted to hay activities for the models, custom harvesting costs of $23 per ton, taken from enterprise budgets for other regions of the state, were assumed.

Municipal sewage effluent is produced by a hypothetical Oklahoma town with a population of 6,000, approximately the mean population of the cities in the study area. Production of 100 gallons per capita per day is assumed, making the daily flow of the municipality 0.60 million gallons per day. Neither the population of the town nor the per capita production of effluent are assumed to change during the model time frame. The net evapotranspiration rate, in keeping with the regional orientation of the enterprise budgets used, is assumed to be 35 inches per year; that rate corresponds with the rate of net evapotranspiration found in much of western Oklahoma.

Three oxidation lagoons and one holding lagoon are assumed. Monthly evapotranspiration was calculated using the surface acreage of the lagoons. The oxidation cells cover a total of 14 surface acres and have an average depth of four feet for each cell. The holding cell covers 20 surface acres and has an average depth of 10 feet. Municipal sewage effluent flows into the oxidation lagoons from the primary treatment plant and remains in those lagoons for a period of 30 days before being released into the holding lagoon. Wastewater in the holding lagoon is then used when required for irrigation. Startup of the land application facility occurs in December of year 0.

No attempt was made to model how municipal sewage effluent and its constituents are affected by application to, and percolation through, the soil. Effluent is applied in the irrigated model at a rate which does not exceed crop and forage water needs. An implicit assumption of such an application rate is that environmental hazards, such as buildup of harmful wastewater constituents or leaching of nitrogen or phosphorus into groundwater supplies, will not be significant.

Since, in a linear programming model, only those resources that are in short supply are imputed a value greater than zero, a scarcity scenario was tested for the representative farm model irrigating municipal sewage effluent. The acreage was set at 300 acres, or 100 acre per tract, while the supply of municipal sewage effluent did not change. This created a situation where the supply of wastewater was not sufficient to irrigate all 300 acres. Dryland forage budgets were available in the model for tracts of land producing forage in a given year. No other conditions changed relative to the 240 acre irrigated model.

Most of the OSU Enterprise Budgets used in the model are budgets representing northwestern Oklahoma. However, certain budgets were used which represent southwestern Oklahoma. Due to this crossing of regional productivity coefficients, the results of the models may not reflect productivity as accurately as is ideal, but model results should be representative of what can be achieved by irrigating crops or forage with municipal sewage effluent in Oklahoma.

Basic Mathematics

Although the structure of each model varies significantly from the other model, the theoretical differences between the two models are slight. The objective function of the irrigation model can be stated as

$$(1) \qquad \max \sum_{j=1}^{n} c_j x_j$$

subject to

$$(2) \qquad \sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad i = 1,\ldots,r$$

$$(3) \qquad \sum_{j=1}^{n} a_{ij} x_j = b_i \qquad i = r+1,\ldots,m$$

$$(4) \qquad x_j \geq 0 \qquad j = 1,\ldots,m$$

where c_j is the return per unit to unpaid resources for the jth activity, x_j is the quantity produced by the jth activity, a_{ij} is the amount of the ith resource required per unit of the jth activity, and b_i is the level of the ith unpaid resource available. Equation (2) states that m number of equations of primal variables are constrained to be less than or equal to the corresponding resource level. Equation (3) states that (m - r) number of equations are constrained to equal the corresponding resource level. These (m - r) equations represent the municipal sewage effluent produced by the city each month. Equation (4) states that all quantities produced are nonnegative. The objective function of the dryland model is identical to that of the irrigation model; the only difference in the two models theoretically is that equation (3), which represents the municipal wastewater supply constraints for each application period, is omitted in the dryland model.

To analyze the value of municipal sewage effluent in optimal agricultural production, the dual solution of the irrigation model was generated, with the optimal values for the dual variables obtained. The theoretical validity of this approach is presented below. Given the objective function in equation (1), the objective function of the dual is

$$(5) \qquad \min \sum_{i=1}^{m} b_i y_i$$

subject to

$$(6) \qquad \sum_{i=1}^{m} a_{ij} y_i \geq c_j \qquad j = 1,\ldots,s$$

$$(7) \qquad y_i \text{ unrestricted} \qquad i = s+1,\ldots,n$$

$$(8) \qquad y_i \geq 0 \qquad i = 1,\ldots,s$$

where y_i is the shadow price, or imputed value, of the ith resource and all other variables have the same meaning as in the primal. There are some significant differences between the dual and the primal with respect to the constraints. Equation (6) contains a reversed sign compared to its counterpart, equation (2), in the primal. Where the primal contains an equality constraint in equation (3), the dual specifies in equation (7) that y_i is unrestricted in sign over the same (n - s) number of equations (Agrawal and Heady). Equation (7), like equation (3) in the primal, does not exist in the dryland model.

The validity of y_i as the imputed value of the ith resource may be proven in several ways. Duality Theorem I (Chiang) states that the optimal values of the primal and the dual objective functions are always identical, provided that an optimal feasible solution exists (for a proof of the theorem, see Henderson and Quandt). When equation (5) is solved and an optimal value is obtained, y_i represents the optimal value for the ith resource used in the available production activities. In a more objective-oriented sense, y_i gives the rate at which the optimal value of equation (5) would increase as b_i increases, given no change in other resource endowments. Since the optimal values of both the primal and the dual are equal, a one unit increase in the ith resource will increase the optimal value of equations (1) and (5) by y_i. This implies that the value of the ith resource as an input in production is optimally represented by the value of y_i in the solved objective function.

Turning to the constraints in the dual, an examination of equation (6) further shows the validity of y_i as the imputed value of the ith resource. The left-handed side of equation (6) represents the total opportunity cost of producing the jth product, since a_{ij} denotes the amount of the ith input used in producing the jth product and c_j denotes the returns per unit of product j. The opportunity cost for using each resource in a given production activity is constrained to be greater than or equal to the per-unit returns from said production activity. Rational economic behavior would dictate that if the opportunity cost of resources in production of a good is greater than the returns from producing that good, then another good will be produced where those greater returns will be realized. Therefore, when the model is optimized, the opportunity cost must equal the returns from production, and the allocation of resources is optimal. For the set of equations represented by equation (6), each y represents the imputed value of each input in s number of production activities.

The unrestricted quality of the y_i's represented in equation (7) is of significant importance in the economic interpretation of the model results. Equation (7) corresponds with the equality constraints of equation (3), which represent the volume of municipal sewage effluent entering the model in a given month. Equation (7) implies that the value of new municipal wastewater in a given month may be positive, negative, or zero. The possibility of negative, or zero, returns from wastewater implies that a volume of municipal sewage effluent available for irrigation in a given month may be in Stage III of production for the production function of a given enterprise. In a land application system which handles a large volume of effluent and/or employs a high loading rate, such a volume may be possible.

Model Components

The variable names are identical for each of the LP models. Appendix C contains the variable names for the models. A picture of two representative years of the irrigation model is located in Appendix D, and a picture of two representative years of the dryland model is located in Appendix E.

The objective of the models is to maximize the net present value of income streams for the farmer for over the 20 year period. The approach used to inject multiple time period impacts into the models was discounting of future net revenues. The objective function for each model can be expressed as:

$$(9) \qquad PV = \sum_{t=1}^{20} \sum_{j=1}^{m} \frac{c_j x_j}{(1+r)^t}$$

where

r is the discount rate,

c_j is net returns per unit of x, and

t is the time period.

The numerator of the fraction in equation (9) represents the annual net income of the farmer for m number of activities. Per-unit net returns were discounted at a rate of 6.0 percent. This figure represents the difference between the nominal interest rate and the rate of inflation.

The production activities available to the farmer in the models are alfalfa, wheat, grain sorghum, and bermuda grass. Alfalfa is grown for hay, wheat and grain sorghum are grown for grain, and bermuda grass is utilized for grazing. AUM coefficients for bermuda grass production, obtained from the enterprise budgets, were converted to tons to approximate hay production. An animal unit was defined as a 1102 lb. cow of average milking ability and a 331 lb. steer or heifer calf with a daily gain of 1.5 lbs., consuming 30.3 lbs. of dry matter per day (Jurgens). The nonadjusted prices used for the agricultural production enterprises were $75.00 per ton for alfalfa, $3.70 per bushel for wheat, $52.00 per ton for bermuda grass, and $4.60 per hundredweight for grain sorghum.

The dynamic elements in the empirical models are capital transfer activities and a net returns constraint in both models, interperiod transfer of stored municipal sewage effluent in the irrigation model, and discounting of future income streams in both models. The discounting process was explained by equation (9).

The irrigation modeling process begins with the monthly inflow of municipal wastewater from the oxidation lagoons. The supply of this new wastewater (the RHS of constraint --Q) is transferred to the corresponding inflow activity (--INFL). An example is shown in equation (10):

(10) JNINFL2 = 655.44.

The quantity of new effluent is transferred to that month's irrigation row (--IR). The irrigation constraint dictates that wastewater can be applied to land as an input to production, placed in storage, or some combination of the two. For example, the irrigation constraint for June of year 2 (JNIR2) is

(11) 4.0(ALFPRD2) + 8.0(BGPRD2) - JNINFL2 + JNSTOR2 - JNSWW2 $\leq$ 0

where

JNSTOR2 is the storage activity for that month.

Wastewater in excess of what can be productivity applied in a given month is placed in storage. The storage activity moves the quantity of stored effluent to a transfer row (--TR) which then moves the effluent to a stored wastewater activity for the following month (--SWW) as shown in equation (12):

(12) JNSTOR2 - JLSWW2 $\leq$ 0.

Equation (12) is the JNTR2 constraint. The stored wastewater activity transfers the unused effluent to the irrigation constraint for the next month. For the examples above, the stored effluent is transferred to irrigation constraint JLIR2. So, as is illustrated in equation (11), there are two potential sources of irrigation water: new effluent coming into the system, and stocks of effluent left over from the previous month.

In both models the producer starts with \$15,000 in operating capital. The operating capital constraint in year 1 (OPCAP1) regulates the use of operating capital in crop and forage production. OPCAP1 for the dryland production model is

$$(13)\quad 11.986(\text{ALFPRD1}) + 18.570(\text{BGPRD1}) + 23.153\,(\text{WHTPRD1}) - \text{BORROW1} + \text{CAPTA1} \leq 15000$$

where

BORROW1 is the capital borrowing activity for year 1, and

CAPTA1 is the capital transfer activity for year 1.

Unused operating capital in year 1 is transferred to the operating capital for year 2.

The models tap another source of funds for operating capital in years 2 through 20. A net return row (NTRET) contains all the c_j's for each activity in a given production period and represents the net present value of income in a given year. The signs of the coefficients of NTRET are reversed from those of OBJ (the objective function). The dryland model NTRET1 is

$$(14)\quad 155.04716(\text{ALFPRD1}) + 19.22641(\text{BGPRD1}) + 16.36792(\text{WHTPRD1}) + .14151(\text{BORROW1}) + 4.00943(\text{LBRBUY1}) + .27358(\text{NBUY1}) + .30189(\text{PBUY1}) - 70.754716(\text{ALFSEL11}) - 49.056603(\text{BGSEL1}) - 3.490566(\text{WHTSEL1}) + \text{NRTA1} \leq 0.$$

NRTA1 is a net returns transfer activity for year 1; it transfers net income in year 1 to the operating capital constraint for year 2 (OPCAP2), shown below:

$$(15)\quad 11.986(ALFPRD2) + 18.570(BGPRD2) + 23.153(WHTPRD2) - CAPTA1 - .1(NRTA1) - BORROW2 + CAPTA2 \leq 0.$$

From equation (15), ten percent of net returns from year 1 is made available for operating capital in year 2.

CHAPTER IV

SURVEY RESULTS

Site Characteristics

A list of general characteristics of the operating land application systems for the communities in the study is presented in Table I. All of the land application systems in the study area are slow rate, irrigation-type systems. Slow rate land application, as opposed to overland flow and rapid infiltration, is the method of land application which lends itself most favorably to agricultural production. Slow rate systems are relatively small in capacity, typically less than 1.0 million gallons per day (mgd) in effluent flow, presenting less opportunity for anaerobic conditions to develop which are detrimental to the productive and treatment capabilities of the system. Utilization of sewage effluent by plants is higher and more efficient in a slow rate system than in either an overland flow or a rapid infiltration system.

Several application methods are used in the study area treatment systems: center pivot, rolling line, water winch, and fixed nozzle sprayer systems. Most of the systems are small sized systems, ranging from 0.084 mgd to 0.61 mgd in system design flow. The system in Ada handles a flow of 2.40 mgd, and the system in El Reno handles a flow of 1.25 mgd.

TABLE I

SELECTED DATA ON OPERATING MUNICIPAL SEWAGE
EFFLUENT APPLICATION SYSTEMS IN OKLAHOMA
AS OF SUMMER 1984

City	1980 Population	Number of People Served By Sewage Plant	Daily Flow (MGD)	OSDH Listed Size (MGD)	Application Site Acreage	Capital Cost
Ada	15,902	15,000[a]	2.4	b	166	$ 101,000
El Reno	15,486	18,000	1.25	2.25	545	2,000,000
Frederick	6,100	6,100	0.35	0.61	115	1,506,562
Marlow	5,017	4,400	0.53	0.60	72	1,352,000
Okarche	1,100	1,100	b	0.084	50	312,930
Sterling	715	285	0.15	0.15	58	500,000
Talala	163	77	0.019	0.20	10	495,000
Walters	2,900	2,900	0.225	0.30	60	771,000

a. Does not include the East Central State University Campus, which also is served by the system

b. Not listed, or no estimate available

The various modes of land acquisition and system management which are used by the municipalities in the study are presented in Table II. Although most of the communities use land owned by farmers, several communities own part or all of the land for their land application systems. Some of these communities have agreements with farmers to produce crops or forage on their treatment site, while two municipalities farm the site themselves.

The types of crops and forages grown on the sites in each municipality's system are listed in Table III. Bermuda grass is the most widely used vegetation among the study area systems, although alfalfa, wheat, corn, native pasture, triticale, and alfalfa interseeded with rye and wheat also are produced. Soybeans and milo have been grown on some of the survey area sites in the past but were not grown in 1984.

Total costs of the land application systems range from $101,000 in Ada to $2,000,000 in El Reno. Variations in total cost between systems are caused in part by fee simple acquisition of land on the part of some municipalities and acquisition via easement or rental agreement on the part of other municipalities.

The relatively low cost of the Ada system is due in part to the objective of the system. Since the effluent is adequately treated conventionally prior to irrigation, the goal is purely utilization of the wastewater for agricultural production. Certain types of equipment did not need to be purchased as a result.

A detailed analysis was made on each of the completed land application systems. Descriptions of the size and climate for each community, the terms of the agreement between city and farmer, the

TABLE II

LAND ACQUISITION AND SYSTEM MANAGEMENT ALTERNATIVES USED IN OKLAHOMA LAND APPLICATION SYSTEMS, AS OF SUMMER 1984

City	Application Site Ownership	Acquisition Option	Length of Agreement (Years)	Management Option
Ada	City	Own Land	n/a	Managed and farmed by city
El Reno	Private	Contract	20	Cash lease to farmer for effluent; farmer also relinquished water rights to city
Frederick	City	Fee Simple	n/a	Leased to farmer
Marlow	Private	Contract	40	
Okarche	Private	Informal	No Set Length	Farmer provides land in exchange for effluent
Sterling	Private	Contract	20/perpetuity[a]	Farmer provides land in exchange for effluent
Talala	Private	Contract	20/99[a]	Farmer provides land in exchange for effluent
Walters	City	Fee Simple	n/a	Managed and farmed by city

a) Responses of farmer and municipal official differ

TABLE III

1984 CROP/FORAGE SELECTION AND ACREAGE ON OKLAHOMA LAND APPLICATION SITES

City	Alfalfa	Alfalfa/ Wheat/Rye	Bermuda Grass	Corn	Native Pasture	Triticale	Truck Crops	Wheat
Ada	--	--	--	--	--	--	--	166
El Reno	185	150	--	80	--	125	--	450
Frederick	--	--	106	--	--	--	--	--
Marlow	--	--	72	--	--	--	--	--
Okarche	--	--	--	--	50	--	--	--
Sterling	20	--	--	--	--	--	3	35
Talala	10	--	--	--	--	--	--	--
Walters	--	--	60	--	--	--	--	--

physical characteristics of each land application system, and the nature of the operation of each system are discussed below. Figures on annual precipitation come from data compiled by the National Oceanic and Atmospheric Administration for the period 1970-1979 (Pettyjohn, White, and Dunn). Evapotranspiration rates are excerpted from OSDH's Design Guidelines for Land Application of Municipal Wastewater.

Ada

The county seat of Pontotoc County, Ada is located in south central Oklahoma, 83 miles southeast of Oklahoma City. The 1980 population was 15,902. The sewage treatment system serves 15,000 residents plus the East Central State University campus. Annual precipitation averages 38-40 inches, and annual evapotranspiration is approximately 56 inches. Disposal of the municipal sewage effluent via discharge into Little Sandy Creek after treatment was the method of handling the wastewater before the installation of the land application system.

The Ada land application system is unique relative to the other systems in the study area in that the single objective of the system is agricultural production; there is no objective for treatment of the municipal effluent. The conventional sewage treatment system treats the effluent to sufficient levels that effluent in excess of what can be applied or stored is discharged into Little Sandy Creek. The application site is the Ada Municipal Airport, owned by the city; the sewage treatment plant is located adjacent to the airport. The city operates the farming enterprises on the application site as well as the irrigation system. A two acre storage cell is located on the airport grounds and is stocked with catfish.

Irrigation with municipal sewage effluent began in July 1982. Two center pivot sprinkler systems are in place, one irrigating 143 acres and the other irrigating 23 acres. One pumphouse serves both center pivot systems. The city uses loading rates on both pivots of 800 gallons per minute and 0.5 acre inches per application. Wheat currently is being grown on both sites; milo was planted in previous years. Annual wastewater application is approximately 17 acre inches for wheat and is usually higher for milo.

The city is considering growing alfalfa on the irrigation sites. Alfalfa is grown on most of the 770 acres in the airport grounds, and the local market for alfalfa is strong due to the large number of horse farms in the area. The municipal officials stated that alfalfa meets two criteria for use of a crop with the application system: it uses a lot of water, and it generates more revenue than other crops. The city officials feel that grain crops do not generate enough revenue. Additionally, alfalfa is compatible with the operation of the airport with respect to safety requirements placed upon the airport.

El Reno

El Reno is the county seat of Canadian County and is located 30 miles west of Oklahoma City on the North Canadian River. The 1980 population was 15,486. An estimated 18,000-19,000 people are served by the sewage treatment plant. Annual precipitation averages 28-30 inches, and annual evapotranspiration is 62 inches.

The municipality and the farmer have a 20 year agreement for use of the municipal wastewater. In exchange for El Reno's effluent, the farmer pays $5,000 per year and has relinquished the water rights on his property to the city. The municipality is responsible for all operation and maintenance (O&M) costs of the system and for repair of the site in the event of bogging of the equipment and the subsequent tracking of the site. Two 45-acre storage lagoons are available from which effluent may be pumped. If the city cannot provide a specified volume of effluent to the farmer, he is allowed to use ground water (which was relinquished to the city) from his old wells.

Certain environmental issues are addressed in the contract. Selected industrial pollutants are prohibited from entering the system, consistent with a city ordinance prohibiting said wastes. The city is responsible for maintaining soil pH on the site. The city is liable for any and all pollution-related damages resulting from the application of the effluent.

The municipality and EPA provided five center pivot sprayer systems to apply the city's effluent on 465 acres. The farmer installed a center pivot system on an additional 80 acres; the agreement stipulates that systems for acreage other than the 465 acres must be purchased by the farmer. The application rates used are two acre inches per application and approximately two acre feet annually. Operation of the application system began in 1981. The farmer irrigates wheat, alfalfa, triticale, corn, and an alfalfa/rye/wheat mix; soybeans have been grown on the site in the past.

Frederick

Located in southwestern Oklahoma within 20 miles of the Red River, Frederick is the county seat of Tillman County. The 1980 population was 6,100, all served by the city sewage plant. The climate is semiarid; annual rainfall averages 26-28 inches, and evapotranspiration exceeds 64 inches per year. Prior to the establishment of the land application system, the city used a trickling filter system to treat its wastewater.

The city owns 200 acres two miles east of town which serves as the primary application site. A smaller site is located adjacent to the airport, also owned by the city. The size of the actual application areas are 115 acres and 20 acres, respectively. Municipal sewage effluent also is used by an oil rig for drilling activities on land adjacent to the 200 acre city property east of Frederick. Attention here is focused on the larger site because the irrigation and farming activities are more intensive at that site.

The farmer and the municipality have a three year lease with one year options in which the farmer pays $6,500 per year for the right to produce a crop on the application site. All operational and maintenance costs are paid by the city. Three lagoons, including one nine acre holding cell, are located adjacent to the irrigation site.

Application of the municipal effluent began in 1983. The city has installed a center pivot irrigation system. Loading rates on the site range from 950-1000 gallons per minute, and monthly flow ranges from 10-16 million gallons. Yearly application of effluent is around 185 million gallons. The farmer irrigates bermuda grass and grazes

Holstein cows on the site. The pasture is stocked at a rate of 1.0-1.5 head per acre. The farmer operates a superovulation program with the cows he grazes on the application site. A total of 106 acres are irrigated due to the fact that the corners of the field cannot be reached by the center pivot sprayer system.

Marlow

Marlow is located in northern Stephens County, 28 miles east of Lawton in southern Oklahoma. The annual precipitation rate averages approximately 30 inches; evapotranspiration occurs at a rate of 62 inches per year.

The municipality's sewage effluent is applied on privately owned land. The city and the landowner have a 40 year agreement with respect to the handling of the wastewater. The city has access to the site to apply an unlimited volume of effluent; the state can intervene, however, in the event of runoff of applied effluent. The farmer operates the application system and determines what crop or forage will be grown on the site. Two treatment cells and one holding cell are located on city-owned land near the application site.

The city uses a center pivot irrigation system to apply the effluent. The system is eight sections in length with a span of 1435 feet. The system application pattern is semicircular, approximately 175 degrees; the location of the application site was changed after the irrigation equipment had been purchased, and the 72 acres of the present site is about half the size of the intended site. The system is designed to irrigate 700 gallons per minute. Application of municipal effluent began in 1983. The site is seeded in bermuda grass.

Okarche

The town of Okarche straddles the border of Kingfisher and Canadian counties in the wheat-producing area of central Oklahoma. Its 1980 population was 1,100, all of which are served by the city's sewage treatment plant. Annual rainfall averages 28-30 inches, and evapotranspiration is around 62 inches per year. Prior to the implementation of the land application treatment system, the city's effluent was discharged into a waterway.

The agreement between the municipality and the farmer concerning use of the effluent is informal. No set time frame is in effect, and no money was exchanged. All O&M costs are the responsibility of the city. No water rights are involved.

Initially, the city intended to install a total retention system, but an engineering error resulted in the construction of two oxidation ponds which were too small for the planned system. As a result, the municipality changed to a land application system. The two lagoons, built in the 1960's, are used in the present system. A 15 acre holding lagoon was constructed in 1978 on city property adjacent to the application site.

The application site is a 100 acre field owned by the farmer. Only 50 acres are presently irrigated; some parts of the field cannot be irrigated due to ditches, gulleys, and sinkholes. The application system consists of a turbine-powered water winch sprayer system with a 150-300 foot dispersion. Loading rates are 300-500 gallons per minute for 36 hours, and monthly loading rates average 1.5 million gallons. The total yearly volume of effluent involved is 12 million gallons since irrigation takes place 8 months out of the year. Irrigation on the present site began in 1984; a five acre city-owned site was used for land application from 1981 to 1983. Native pasture is irrigated on the site, and 65 head of commercial stocker cattle are grazed on the site.

Sterling

Sterling is a small community in northeastern Comanche County. The topography of the area is gently rolling, differing from that of most of Comanche County which is generally flat. Population in this southwestern Oklahoma town in 1980 was 715; 285 residents are served by the sewage treatment plant. Rainfall averages 28 inches per year, and annual evapotranspiration is 62-64 inches. Retention ponds and discharge into Little Beaver Creek were the methods of disposal before the land application system was installed.

The city has an agreement to use a farmer's 65 acre field adjacent to lagoons on city-owned land south of town. The farmer uses surplus water in the holding cell for irrigation of crops; he is required to apply effluent contained within the upper two feet of the holding pond. No money was exchanged in the agreement, and no water rights were involved. The city pays for water sampling and all O&M costs on city property (the 15 acre lagoon area).

The irrigation system is a rolling line sprayer. The loading rate per application is two acre inches, with a total volume of 65 acre feet annually. Application started in June 1983. The farmer primarily grows wheat and alfalfa on the application site; a small acreage of cantaloupe and watermelon also are raised. In 1983, only the truck crops were grown.

Talala

Talala is a tiny community near Oologah Lake in northern Rogers County, situated nearly equally between Tulsa and the Kansas border in northeastern Oklahoma. Talala has a population of 163 with an estimated 77 people served by the local sewage treatment concern, Talala Public Works. The region, referred to as Green Country, has slightly undulating terrain and more vegetation than most regions of the state. Annual rainfall averages 40 inches, and evapotranspiration is 50-52 inches per year. The climate tends to be humid. The method of handling municipal effluent used prior to land application was septic tanks.

The city has a lease agreement with a farmer on a 10 acre site 1/2 mile south of town. An additional 10 acres for three lagoons were purchased by the city from the farmer at a price of $20,000. The farmer has a 20 year agreement to take Talala's effluent on the site, and the city has a 99 year easement for access to the lagoons. The farmer gets the benefits of the water. No money is exchanged between the farmer and the municipality. All operational and maintenance costs are paid by the city from sewer rates. No water rights were involved in the agreement.

The irrigation system consists of fixed sprinklers set 120 feet apart fed by underground water lines. The contract stipulates that application rates do not exceed 0.25 inches per hour and that annual application of wastewater will be 30 inches. Land application began in April 1982. The farmer has grown alfalfa on the 10 acre site for each of the three years of operation.

Walters

The city of Walters is the county seat of Cotton County in southwestern Oklahoma. Located 13 miles north of the Red River, the topography is generally flat and the climate is semiarid. Precipitation averages 28-30 inches per year; annual evapotranspiration is approximately 64 inches. The 1980 population was 2,900. All the residents are served by the city's sewage treatment plant. The previous treatment method used was Imhoff tank and trickling filter.

The land application site is located on city-owned property. The 60 acre site is also farmed by the municipality. Operation of the system began in May 1982. Two center pivot sprayer systems are used to apply the effluent. One of the rigs is a 290 foot mobile unit that can be moved to one of several pivots in the field. The stationary irrigation unit is 580 feet in length. Loading rates vary with the pivots; the permanent unit is designed to handle 800 gallons per minute while the portable unit's design rate is 400 gallons per minute. A permanent stand of bermuda grass utilizes the municipal wastewater.

Land Application Sites No Longer In Operation

The search for land application systems for the study revealed some communities that had used land application in the past. However, for various reasons, these municipalities had ceased operations at their facilities. The impetus for shutdown of each of the treatment facilities was related to the agreement between city and landowner.

Pauls Valley had used land application as a component in the city's wastewater treatment system since the mid 1960's. Municipal effluent was applied to land at Pauls Valley State School through a cooperative agreement between the city and farm managers at the school. The Oklahoma Department of Human Services, which oversaw operations at Pauls Valley State School, ceased operations at the school in 1983. The city, in turn, had to shut down its facility until an agreement could be made between a farmer and the Department of Human Services to lease the land. A consequence of not irrigating the effluent was a backup of effluent in the lagoons and a subsequent overflow of untreated wastewater into a nearby waterway.

Kingfisher employed land application for treatment of the city's effluent from 1973 to 1982. The city had an informal agreement with a farmer for use of the effluent. The farmer died, and the city has not found another landowner to take the effluent. Elmore City had a similar experience. The city constructed a land application facility on a farmer's property. The farmer died before the facility could begin operations; the irrigation system remains on the site and has never been used. The city has since constructed a total retention system.

Observed Benefits

The Oklahoma land application systems investigated by the survey exhibited both benefits and problems to the communities and landowners.

Some of the benefits observed by the on-line systems were sought by the municipalities, constituting the reason or reasons the municipality chose a land application system. Other positive aspects of irrigation of municipal sewage effluent have accrued even though they were not anticipated by either the city or the farmer.

A positive aspect of wastewater irrigation which was significant among the survey area systems was the increased stability of the water supply for crop or forage production. In Frederick, the summer months bring on conditions which decrease the efficiency of irrigation and increase consumption of water by plants. Windy conditions and the temperature, which may rise as high as 110 degrees, combine to greatly raise the evapotranspiration rate during this period. Similar conditions exist to varying degrees throughout central and western Oklahoma during the summer. The city official in Talala noted that, with the presence of the land application system, crop production was not dependent upon rainfall.

A benefit of land application reaped by the farmers was the utilization of plant nutrients found in municipal sewage effluent in production of crops or forage on the application site. The survey revealed that producers valued the nitrogen and phosphorus in municipal wastewater highly. The farmer in El Reno would not permit the city to stock the holding lagoon with catfish for fear that the fish would use up nutrients that he wanted on his crops. City officials also recognized the importance of nutrient components of municipal wastewater; most officials saw plant nutrient content of their municipal effluent as a positive factor in marketing the effluent to farmers.

Production was increased significantly, sometimes twofold, through irrigation with municipal effluent, according to nearly all the producers surveyed. The officials in Ada stated that their land application system pays for itself in a dry year when rainfall is insufficient for normal crop production. Most farmers stated that the level of production of the irrigated crop or forage would decrease if the municipal effluent was either no longer available or no longer economically feasible to pump.

Demand for municipal sewage effluent as a source of irrigation water was strong in several communities surveyed. The farmer of Frederick's primary site, who produced bermuda grass and grazed Holstein cows on city-owned land, expressed a strong interest in using the effluent on his own land. However, his farm is located 18 miles from Frederick near Chattanooga, and transportation costs of the effluent would be prohibitive. The municipal official mentioned that another farmer had expressed interest in using the city's wastewater, but transportation to that farmers land was not feasible. No farmers adjacent to the existing application sites had expressed interest in irrigating with Frederick's effluent.

The city of Blanchard, despite opposition to a land application system by landowners around the city-owned site, is working on an agreement with two farmers to take the effluent on their farms. A third farmer wanted to use the effluent, but his land was 12 miles away. The city official in Medford expected several farmers to express interest in using the municipal effluent; one farmer had already indicated that he was interested in irrigating with the city's effluent. Medford's proposed system, in design stage at the time of the survey, was to use city-owned land one mile from the present sewage treatment facility. The official felt that reaching an agreement with a farmer to take the effluent was likely.

Land application of municipal wastewater was, in the view of nearly all municipal officials, a relatively low-cost method of handling a city's sewage effluent. When asked how costs of land application compared with those of other methods of handling municipal sewage effluent, the majority of city officials answered that land application costs were either lower or much lower than costs of alternatives. The responses of the city officials are presented in Table IV.

Several municipal officials viewed their land application systems as transforming a "waste" into a "resource." Where once a community was looking for a way to dispose of unwanted sewage effluent, it could reclaim both the water and the nutrients in the wastewater by irrigation of crops or forage. Responses by the municipal officials indicated an awareness on their part of the objective of waste reclamation as opposed to waste disposal. The official in Sterling stated that the system was 50 percent disposal and 50 percent reclamation. Talala's official saw land application with an agricultural production component as reclamation of wastes, stating that some attitudes toward waste utilization in general should be changed.

Operational and Environmental Problems

The survey revealed a variety of drawbacks encountered by the municipalities with respect to the operation of the land application

TABLE IV

COMPARISON OF LAND APPLICATION CONSTRUCTION COSTS TO ALTERNATIVE TREATMENT METHODS - RESPONSES OF SURVEY AREA MUNICIPAL OFFICIALS[a] IN 1984

Land Treatment Costs Compared With Alternatives	
Much Higher	0
Higher	0
Similar	0
Lower	3[b]
Much Lower	1
Not Sure	2
Other	1[c]

a) Cities Responding: Ada, Cyril, Frederick, Okarche, Sterling, Talala, Walters

b) The official in Okarche responses that land application was lower in cost than conventional treatment but much higher than the total retention method.

c) Ada does not utilize the land application method for treatment purposes.

system and potential or actual hazards to the environment. Such problems were found in both on-line and off-line treatment systems. Not all municipalities surveyed have problems with their systems; the intent of this section is to highlight, by using communities' experiences, the potential negative aspects of using land application for both effluent treatment and agricultural production. The types of problems encountered by the municipalities range from physical to engineering to managerial in nature.

One of the more common problems found among the systems surveyed is erosion of the holding cell dikes from wave action of the surface water. Some municipalities, such as Sterling, have not as yet experienced a significant amount of erosion but are monitoring the situation closely and taking preventive action. Other municipal systems, such as the one at Marlow, have experienced significant dike erosion and have had to take steps to both repair the damage and abate the waving action. Measures taken or considered by communities to combat waves in the cells were baffling cell banks with either rip rap rock or styrofoam-filled tires chained together to break the waves.

A problem which is related in its effects to dike erosion is seepage in either the dikes or the floor of the holding cells. As with dike erosion, seepage from the lagoons poses a health risk to the community in the form of escape of untreated sewage effluent. This enhances the potential of pollution of both the soil and the groundwater supply. Also, the surrounding landowners or the community at large may bring civil action against the municipality in the event of leakage of effluent from the lagoons. Walters has had to drain one of its eight acre lagoons due to seepage. El Reno also has had to drain one of its lagoons and install new liners. Blanchard has experienced delay in bringing its system on-line in part because the lagoons were not properly sealed; 50 million gallons had to be pumped out of the cells to make corrective measures. In both Walters and Blanchard the cells required the application (or reapplication) of bentonite to seal the cell floors and walls.

System design has not always met all site-specific conditions among the survey area land treatment systems. Lenapah's system has been in place since 1981. However, the water level in the holding pond has evaporated so quickly that the volume of effluent has never been sufficient to irrigate (according to OSDH guidelines, a minimum level of four feet of effluent must remain in the holding cell to retard algal growth). Talala has experienced similar difficulty in retaining the minimum required volume of wastewater in the holding cell, although application of the effluent has taken place since 1982. In the case of Talala, the land treatment system was designed for a population of 300; Talala's population at the time of the survey was 163. Because of the system size discrepancy, OSDH had suggested that, with proper management, Talala could convert its treatment system from land application to total retention.

Several land application sites have experienced problems with bogging and/or tracking of irrigation equipment on the land. The severity of this problem was found to vary from slight to severe. Generally, bogging and tracking was a problem where infiltration or percolation of wastewater was relatively slow, due to applying effluent to heavy clay soil, to high loading rates of effluent, or both. Both sites used by Frederick have experienced tracking by the center pivot system. The primary site has suffered slight damage in a few of the outermost areas of the field; the smaller site has been modified to eliminate bogging of the transport wheels by paving the paths of the wheels with asphalt. Marlow's site has suffered bogging of the center pivot system to the extent that system operation has occasionally been halted. The ruts dug by the wheels have caused water to collect in the path the system must travel, perpetuating the risk of bogging and system shutdown.

For various reasons, infiltration and/or percolation may be insufficient to handle the rate of wastewater applied. The result may be ponding of sewage effluent on the land surface or even runoff of wastewater from the application site, which could lead to negative reactions by community citizens as well as causing soil or groundwater contamination. Ponding has occurred at the Marlow site. Bogging of the irrigation system wheels has resulted, and treatment effectiveness was diminished. Runoff of effluent collected on the surface had not occurred but could pose a serious problem; a pond on a neighboring farm lies adjacent to the application site. The city of Frederick has had to be cautious about the potential of runoff of its effluent from the main site. A grass waterway crosses from the field to a neighbor's property which has drainage problems. Conflict between the city and the landowner has occurred in the past over collection of water on the neighboring farmland and whether the city was responsible for ponding of water on the neighboring farm.

Negative attitudes on the part of the residents on a community have the potential to delay operation of a land treatment system or increase the cost of the system to the city. An example of such an impact was the experiences of the city of Blanchard. Public opinion on the part of landowners in the community ran against reuse of municipal sewage effluent at the time of the survey, according to the municipal official. Lawsuits were threatened by landowners adjacent to the city's application site because of the seepage problems in the holding cell. The landowners wanted the city to buy their properties if the land application plan was implemented.

A significant problem which was encountered among study area systems was seasonal storage limitations of municipal effluent. Certain cities, such as Frederick, have a buildup of wastewater during the period of December through March while more wastewater than was available could have been utilized by the crop or forage in July and August. Application of sewage effluent in the winter months has been practiced at the Sterling system. Any effluent two feet from the top of the holding cell must be applied, according to the agreement; this surplus wastewater was subject to application no matter what the season.

As has been indicated above, some of the land treatment systems have applied municipal sewage effluent at loading rates which were not optimal with respect to agricultural production. Water usage often followed the pattern exhibited at the Frederick system. In the cooler months, plant demand for water decreased; during hot months such as July and August, demand for water by plants increased significantly, as did the evapotranspiration rate. Irrigated wastewater often evaporated before reaching the soil. The ponding of wastewater at the Marlow site inhibited growth of the bermuda grass on a significant area of the site.

The control of weeds around the lagoons was a concern at some municipal systems. The Oklahoma State Department of Health requires plant growth around the area of the holding and oxidation cells to be controlled within certain limits. Some communities, however, have had problems with making arrangements for mowing or other methods of weed control. Talala had no specific plan for weed control, but the municipal official was looking into the use of herbicides. Other municipalities have implemented unique methods for keeping weeds under control. Sterling and Lenapah both utilize goats to control plant growth around the lagoons.

Management of the operation of the land application system emerged (from the interviews) as a paramount factor in the operation, whether successful or unsuccessful, of a municipal wastewater irrigation system. The city official in Frederick emphasized that management was important in their system, particularly the timing of application of wastewater. The possibility of surface runoff onto adjacent property in their case was a major concern. The official, in his support of good system management, expressed dissatisfaction in the "pat answer" of "build more lagoons" for any system problems which may occur. Physical problems may exist which require more intensive management on the part of either the municipality or the landowner. Marlow's site proved this point. The soil type at the site allows water to percolate at a rate of 0.2 to 0.8 inches per hour; application rates in the past have exceeded one inch per hour.

CHAPTER V

EMPIRICAL MODEL RESULTS

The model results for the irrigated and dryland models were derived by using the Mathematical Programming System - Extended (MPSX) linear program. Using the IBM 3081 computer at Oklahoma State University, the MPSX routine was called to optimize the objective function and measure the sensitivity of the solution via the range feature. Program output was used to analyze the profitability of municipal sewage effluent irrigation and the value of effluent as an input in agricultural production for Oklahoma farms.

The first section of this chapter deals with input demand, input supply, and costs for the linear programming models. The second section covers a comparison of the results of the irrigated production and dryland production models described in the first section and in Chapter III. The third section discusses the implications of the storage of wastewater in the irrigated models. The fourth section pertains to the economic evaluation of municipal sewage effluent in a situation where the demand for irrigation water is greater than the supply of municipal effluent during part or all of the production period.

Resource Requirements, Levels, and Costs

The requirements for irrigation water per acre by month, year, and crop are shown in Table V. Demand for irrigation water in general by plants is greatest during the period of April through September. Alfalfa and bermuda grass require the most water during the year (33 and 32 acre inches per year, respectively). The rotation of grain sorghum with alfalfa every sixth year decreases the irrigation requirements by nine acre inches during those years when grain sorghum is produced. Wheat requires the lowest volume of irrigation water per year. Also, since it is a winter crop, wheat uses water in periods when other crops and forages are either dormant or not planted.

The total monthly water demand for a farm operation at full capacity (240 acres) is calculated by multiplying the monthly requirements of water for each crop (Table V) by 80 acres and summing the products for the month. The monthly demand for irrigation water in acre inches is presented in Table VI.

The net inflow of effluent from the hypothetical town of 6,000 population is shown in Table VI. Starting with a daily flow of 0.60 mgd, evapotranspiration is assumed in each month at a rate of 62 inches annually, distributed appropriately among the months of the year. Annual precipitation of 30 inches adds to the water stock in the lagoons, so an annual net evapotranspiration rate of 35 inches is used to derive the net inflow into the holding lagoon. Evapotranspiration is assumed to occur both in the holding lagoon for a given month and in the oxidation lagoons for the previous month. The net inflow in Table VI, therefore, is a measure of new effluent available for irrigation for a given month.

TABLE V

MONTHLY IRRIGATION WATER REQUIREMENTS, BY CROP, IN INCHES PER ACRE, FOR OKLAHOMA, 1984 CONDITIONS

Month	Alfalfa	Bermuda Grass	Wheat	Grain Sorghum[a]
January	--	--	--	--
February	--	--	--	--
March	--	--	3.0	--
April	6.0	--	3.0	--
May	3.0	4.0	6.0	6.0
June	4.0	8.0	--	3.6
July	8.0	8.0	--	7.2
August	8.0	8.0	--	7.2
September	4.0	4.0	3.0	--
October	--	--	--	--
November	--	--	3.0	--
December	--	--	--	--
TOTAL	33.0	32.0	18.0	24.0

Source: Oklahoma State University Enterprise Budgets

[a]Water requirements for years 6, 12, and 18

TABLE VI

MONTHLY NET INFLOW OF MUNICIPAL SEWAGE EFFLUENT IN ACRE INCHES, CROP WATER USE, AND MODEL DESIGN NET BALANCE, OKLAHOMA REPRESENTATIVE FARM, 1984 CONDITONS

Month	Gross Inflow	Net Evapotranspiration	Net Inflow	Crop Water Use[a]	Balance
January	685	36	649	0	649
February	619	43	576	0	576
March	685	69	616	240	376
April	663	104	559	720	-161
May	684	126	559	1040	-481
June	663	138	525	960	-435
July	685	157	528	1280	-752
August	685	160	525	1280	-755
September	663	134	529	680	-351
October	685	105	580	0	580
November	663	74	589	240	349
December	685	46	639	0	639
TOTAL	8066	1192	6874	6640	234

a) The representative farm has 80 acres each of alfalfa, bermuda grass, and wheat.

Using the net inflow figures from Table VI and the irrigation water requirements from Table V, the monthly net balance of municipal sewage effluent also was calculated and is shown in Table VI. The water requirements used are those for production of alfalfa, bermuda grass, and wheat. From October through March, municipal sewage effluent is accumulating in storage. From April through September, a net volume of effluent is being drawn from storage, due to both high crop demand and increased evapotranspiration. In this particular system, a surplus of 234 acre inches, or 20 acre feet, occurs each year. This factor will be addressed later in the chapter.

The machinery complements for the irrigated and dryland models are listed in Appendix F. Requirements for inputs other than irrigation water are in Table VII. The input-output coefficients, machinery specifications, and cost figures were taken from the OSU Enterprise Budgets in Appendix B. The input cost figures include fixed costs of farm machinery and variable costs other than labor, operating capital borrowing, and commercial fertilizer purchasing. Annual yield coefficients per acre, base prices paid, and gross receipts per acre for the model production enterprises are listed in Table VIII.

Irrigated Versus Dryland Production

The net present value of returns to land, risk, and management was much greater for the irrigated model than that for the dryland model. The discounted net returns in each year for both models are shown in Table IX. Net returns to fixed assets and management were $441,186.87 for the irrigated model and $82,512.00 for the dryland

TABLE VII

ANNUAL INPUT REQUIREMENTS AND BASE YEAR COSTS PER ACRE FOR CROP AND FORAGE ENTERPRISES IN OKLAHOMA, 1984 CONDITIONS

		Units	Alfalfa	Bermuda Grass	Grain Sorghum	Wheat
Labor	IRR.	Hours	11.07	1.66	2.33	1.92
	DRY	Hours	4.01	0.22	0.66	0.78
Operating Capital	IRR.	Dollars	14.32	36.15	58.84	65.27
	DRY	Dollars	11.99	18.570	9.45	23.15
Nitrogen	IRR.	Pounds	--	200.00	130.00	115.00
	DRY	Pounds	--	100.00	35.00	30.00
Phosphorus	IRR.	Pounds	100.00	40.00	50.00	40.00
	DRY	Pounds	60.00	20.00	--	30.00
Other Input Costs	IRR.	Dollars	237.33	80.36	84.58	78.72
	DRY	Dollars	164.35	43.38	46.19	44.41

TABLE VIII

ANNUAL PRODUCTION PER ACRE AND BASE YEAR PRICES
FOR PRODUCTION ENTERPRISES, 1984
OKLAHOMA CONDITIONS

Crop or Forage	Yield/Acre (Unit)	Base Price	Gross Receipts/Acre
Alfalfa, irrigated	6.5 T.	$75.00	$487.50
Alfalfa, dryland	3.0 T.	75.00	225.00
Bermuda grass, irrigated	4.4 T.	52.00	231.09
Bermuda grass, dryland	2.3 T.	52.00	118.17
Grain sorghum, irrigated	56.0 cwt.	4.60	257.60
Grain sorghum, dryland	21.0 cwt.	4.60	96.60
Wheat, irrigated	55.0 bu.	3.70	203.50
Wheat, dryland	22.0 bu.	3.70	81.40

TABLE IX

PRESENT VALUE OF NET RETURNS TO SELECTED FACTORS[a] FOR IRRIGATION AND DRYLAND MODELS, 1984 OKLAHOMA CONDITIONS

Year	Irrigated Model	Dryland Model
1	$ 21,394.67	$ 3,410.49
2	37,428.12	7,086.51
3	35,047.42	6,685.38
4	32,627.19	6,306.97
5	30,753.23	5,575.39
6	22,848.05	5,172.08
7	27,272.71	4,918.41
8	25,770.62	4,637.62
9	24,298.56	4,372.61
10	22,910.85	4,122.91
11	21,603.04	3,887.56
12	16,045.94	3,633.54
13	19,178.35	3,456.47
14	18,113.57	3,259.65
15	17,081.61	3,073.90
16	16,108.63	2,898.81
17	15,191.40	2,733.74
18	11,272.99	2,555.43
19	13,496.32	2,431.33
20	12,743.60	2,293.20
TOTAL	$441,186.87	$82,512.00

a) Land, risk, and management
Net present value is based on a 6.0 percent discount rate.

model. Income for each year is much greater in the irrigated model than in the dryland model. Both models produced all 240 acres available in every year.

Nitrogen and phosphorus are applied in the irrigated model in excess of crop requirements. The extra plant nutrient application comes from nitrogen and phosphorus in the sewage effluent, given the base level of commercial fertilizer application assumed in the irrigated model. Phosphorus was always at excess levels. Nitrogen exceeded crop requirements in 17 of the 20 years; nitrogen fertilizer was purchased in years 6, 12, and 18, when grain sorghum replaced alfalfa in the crop rotation. In those years, approximately 29 pounds of nitrogen fertilizer per acre were purchased.

To analyze more clearly and intensively economic influences in the models, a representative year, year 2, is highlighted from each model. The results of the farm operations (irrigated and dryland) with the levels of input use and agricultural production are presented in Table X.

Both farms produced 240 acres of crops and forage. Labor use was much higher for the irrigated model, and the use of operating capital was also more intensive. Labor was in slack in both models (1328 hours in the irrigated model and 2107 hours in the dryland model). The irrigation model enterprises produced more than those of the dryland model.

The higher requirements for labor and operating capital in the irrigation model illustrate a trade-off between dryland production and irrigated production with municipal sewage effluent in Oklahoma. The difference between the two models' labor and operating capital

TABLE X

FARM OPERATION FOR IRRIGATED AND DRYLAND MODELS, YEAR 2, 1984 OKLAHOMA CONDITIONS

	Unit	Irrigated	Dryland
Alfalfa acreage	acre	80	80
Bermuda grass acreage	acre	80	80
Wheat acreage	acre	80	80
Labor used	hours	1,172	393
Operating capital used	dollars	9,259	4,297
Alfalfa sold	tons	520	240
Bermuda grass sold	tons	871	182
Wheat sold	bushel	4,400	1,760
Net returns to land, risk and management	dollars	37,428	7,087

requirements is approximately $4055 in nondiscounted dollars. Farmers, with less available personal or family labor and/or less flexible capital would need to consider the opportunity costs of those resources in other endeavors for their own situations.

Shadow prices for selected year 2 inputs are shown in Table XI. These values reflect the relative worth of one unit of the input in production; if one more unit of the input is available, the objective function value will increase by the value of the shadow price. In production theory, these shadow prices are synonymous with the value of marginal product (VMP) of an input, or the change in output with a unitary change in input, ceteris paribus, multiplied by the output price. An additional acre of land in alfalfa production in year 2 would increase net income by $223.66 for the irrigated model and by $35.95 for the dryland model. Similar results occur for bermuda grass and wheat acreage.

The sensitivity of the shadow prices was measured by the range function of MPSX. The function finds the range over which the shadow prices hold and what activities bound the range. The ranges for the shadow prices in Table XI are shown in Table XII. For alfalfa in the irrigation model, a one acre change in production will change income by $223.66, if between 0 and 87.1 acres of alfalfa are produced.

Impacts of Wastewater Storage

Keeping year 2 as a representative year, the operational and economic impacts of storage of municipal sewage effluent in the irrigated model are analyzed. The stocks of effluent at the end of each month in year 2 are shown in Table XIII. The pattern of storage

TABLE XI

SHADOW PRICES FOR LAND INPUTS FOR IRRIGATED AND DRYLAND MODELS, YEAR 2, 1984 OKLAHOMA CONDITIONS

	Irrigated	Dryland
Alfalfa acreage	$223.66	$35.95
Bermuda grass acreage	131.25	33.35
Wheat acreage	104.15	14.20

TABLE XII

RANGE SHADOW PRICES FOR LAND INPUTS FOR IRRIGATED AND DRYLAND MODELS, YEAR 2, 1984 OKLAHOMA CONDITIONS

	Irrigated	Dryland
Alfalfa acreage	0 - 87.1 A.	0 - 119.1 A.
Bermuda grass acreage	0 - 86.7 A.	0 - 101.5 A.
Wheat acreage	41.6 - 87.9 A.	0 - 95.1 A.

TABLE XIII

STORAGE OF MUNICIPAL EFFLUENT, YEAR 2, 240 ACRE OKLAHOMA REPRESENTATIVE FARM, 1984 CONDITIONS

Month	End of Month Storage Acre Inches
January	2217
February	2793
March	3170
April	3008
May	2527
June	2092
July	1341
August	586
September	235
October	815
November	1164
December	1803

levels is similar to the pattern of the model design net balance found in Table VI, showing the seasonal nature of water demand by crops and evapotranspiration.

An important issue in land application systems is revealed by the figures in Table XIII. The capacity of the holding lagoon is 2,400 acre inches. The amount of effluent to be stored exceeds the capacity of the holding cell during the period of February through May. Even though land application systems are designed to balance water inflows and water losses, seasonal capacity problems such as this can arise. For land application systems in a situation where winter storage of wastewater may exceed the capacity of the holding cell, municipal sewage effluent would have to be applied during periods of little or no crop use. For the irrigated LP model, we can assume that effluent will be applied during October, December, January, and February as is necessary to avoid overflow of effluent from the holding lagoon. The volume of effluent in excess of storage capacity is not great enough to exceed the handling capacity of the soil during the winter months and should pose no increased environmental hazard.

The shadow prices for effluent inflow in year 2 and the range for which the shadow prices hold are listed in Table XIV. Because storage is never depleted in the model for any month past September of year 1, the shadow prices for every month is equal to the price in the objective function for December storage in year 20 (which was injected into the model to insure storage of effluent). The implication of the very small shadow price is that additional inflow of municipal sewage effluent has essentially no value to the farmer as an input. The ranges for the shadow price reinforce that implication; there is no

TABLE XIV

SHADOW PRICES AND RANGES FOR MONTHLY INFLOWS OF EFFLUENT, YEAR 2, 240 ACRE OKLAHOMA REPRESENTATIVE FARM, 1984 CONDITIONS

Month	Net Inflow Acre Inches	Shadow Price	Range for Shadow Price Acre Inches
January	650	$.0001	414 - infinity
February	576	.0001	341 - infinity
March	616	.0001	381 - infinity
April	559	.0001	324 - infinity
May	559	.0001	324 - infinity
June	525	.0001	290 - infinity
July	528	.0001	293 - infinity
August	525	.0001	290 - infinity
September	529	.0001	292 - infinity
October	580	.0001	110 - infinity
November	589	.0001	119 - infinity
December	639	.0001	169 - infinity

upper limit to the volume of wastewater which can enter the system in any month above which the shadow price will change. The lower limits indicate the volume of inflow of effluent below which the shadow price will change (presumably increase in value). For example, if less than 324 acre inches of new effluent are available in May, the shadow price will change.

Value of Effluent Under Scarcity

In the irrigated production model, the shadow prices for municipal sewage effluent were infinitesimal after year 1 and had no value as a direct price for effluent as irrigation water. To obtain direct VMP's for effluent and a direct value of wastewater as a production input, a scenario was tested using the irrigation model where municipal sewage effluent was in shortage relative to crop water demand and evapotranspiration loss. The total acreage of the farm was increased to 300 acre (100 acres per tract) while the daily flow of municipal wastewater was held constant at 0.60 mgd. The results of the MPSX run with the above assumptions are analyzed and compared with the previous run of the irrigation model.

The number of acres irrigated in the scarcity scenario is shown in Table XV. The 300 acre model run did not irrigate all available acreage in any year, although all 300 acres were under production in every year. After the startup year, the total acreage irrigated ranged from 256 to 284 acres. All alfalfa, wheat, and grain sorghum acreages were irrigated in the model. Bermuda grass irrigation in tract B ranged from 8 to 84 acres, usually occurring at a level of 56 acres; the balance of tract B is produced under dryland conditions.

TABLE XV

ACREAGE IRRIGATED UNDER EFFLUENT SCARCITY, 300 ACRE OKLAHOMA REPRESENTATIVE FARM, 1984 CONDITIONS

Year	Tract A	Tract B	Tract C
1	100	8	100
2	100	56	100
3	100	56	100
4	100	56	100
5	100	56	100
6	100	84	100
7	100	56	100
8	100	56	100
9	100	56	100
10	100	56	100
11	100	56	100
12	100	84	100
13	100	56	100
14	100	56	100
15	100	56	100
16	100	56	100
17	100	56	100
18	100	84	100
19	100	56	100
20	100	56	100

Irrigated bermuda grass acreage increases significantly in years 6, 12, and 18 when grain sorghum, which requires less water annually than alfalfa, enters the crop rotation.

Year two was chosen as a representative year to contrast the 300 acre model characteristics with those of the 240 acre model. The monthly volume of municipal sewage effluent in storage for year two is shown in Table XVI. The same pattern of seasonal fluctuation of water balance in the 240 acre irrigated model holds for this model. The stock of sewage effluent was completely exhausted in September; this happened every year and was the primary constraint on the acreage which could be produced.

The shadow prices for effluent inflow in year two and the ranges over which those shadow prices hold are shown in Table XVII. The explicit value for an additional acre inch of wastewater an an input in production is $2.01 from January through September and $1.92 from October through December. The ranges for the shadow prices indicate the upper and lower limits for which the VMP of effluent remains at the aforementioned rates. Below 0 acre inches of net inflow, May effluent inflows would be worth more; the reverse is true for net inflow above 1906 acre inches for the same month.

The shadow prices for effluent inflow for the twenty year period, as shown in Figure 2, decline at a steady rate after the startup year, reflecting the discounting of future net returns. Given the Oklahoma representative farm approach of the LP models, the shadow prices represent the highest practical value for municipal sewage effluent in production of the crops in the model. The changes in the shadow price level occur in October after the total depletion of sewage effluent in storage in September, and usually in January.

TABLE XVI

STORAGE OF EFFLUENT IN SCARCITY SCENARIO, YEAR 2,
300 ACRE OKLAHOMA REPRESENTATIVE FARM,
1984 CONDITIONS

Month	End of Month Storage Acre Inches
January	2157
February	2733
March	3335
April	3278
May	3107
June	2432
July	1360
August	286
September	0
October	580
November	1154
December	1793

TABLE XVII

SHADOW PRICES AND RANGES FOR EFFLUENT INFLOW IN SCARCITY SCENARIO, YEAR 2, 300 ACRE OKLAHOMA REPRESENTATIVE FARM, 1984 CONDITIONS

Month	Shadow Price Per Acre Inch	Range of Shadow Price Acre Inches
January	$2.01	0 - 1996
February	2.01	0 - 1923
March	2.01	0 - 1964
April	2.01	0 - 1906
May	2.01	0 - 1906
June	2.01	0 - 1872
July	2.01	0 - 1875
August	2.01	0 - 1873
September	2.01	0 - 858
October	1.92	0 - 1927
November	1.92	0 - 1936
December	1.92	0 - 1987

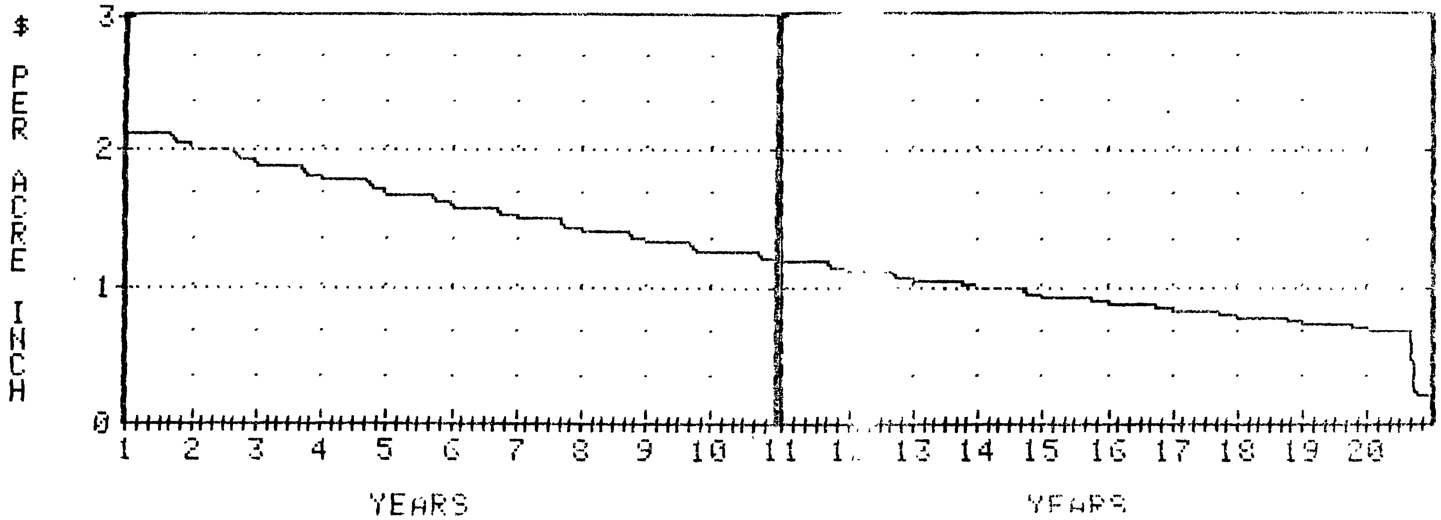


Figure 2. Effluent Shadow Prices, 300 Acre Oklahoma Representative Farm, 1984 Conditions

The shadow prices ranged from \$2.13 per acre inch from January through September in year 1 to \$0.69 per acre inch from January through September in year 20. The shadow prices for effluent inflows after September of year 20 have little meaning. The only activity that uses effluent to increase the model objective value after September of year 20 is December storage in year 20, which was assigned a small positive c_j value to require the model to store effluent throughout the 240 application periods.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

This study investigated the economic and environmental impacts on Oklahoma municipalities, farmers/landowners, and communities as a whole of irrigation of municipal sewage effluent. The primary perspective of the study was that the land application treatment method can be used more efficiently in Oklahoma by emphasizing the farmer's goals of profit maximization and efficient use of effluent as an input in agricultural production. Linear programming modeling and surveys of both municipal officials and farmers involved with Oklahoma land application systems comprised the methodology of the study.

A list of Oklahoma municipalities having or constructing land application wastewater treatment facilities was obtained from the Oklahoma State Department of Health (OSDH). Names of farmers or landowners who irrigated municipal sewage effluent on their property were obtained from the municipal officials having authority over land application systems. Municipalities with completed land application systems investigated in the study were located in the counties of Canadian, Comanche, Cotton, Kingfisher, Nowata, Pontotoc, Rogers, Stephens, and Tillman. Additional information was gathered via telephone interviews with municipal officials having authority over land application systems under construction; these officials were located in communities in Adair, Caddo, Garvin, Grady, Grant, Kingfisher, McClain, and Texas counties.

The land application systems in operation that were surveyed were generally small-sized systems of less than 1.0 mgd in flow rate. The mean acreage of the eight land application systems featured in Chapter IV is 134.5 acres; the mean excluding the El Reno system is 75.86 acres. The crops used most frequently in the systems surveyed were bermuda grass, alfalfa, and wheat.

Ownership of the land was generally private, although many cities either used municipal land, such as airport grounds, or purchased land from the farmer. In systems with privately-owned land, the agreement between city and landowner was usually contractual. Some municipalities, however, had no formal agreement with the landowner. The most common management option used was an exchange of the city's effluent for access to the farmer's land. Two municipalities cash lease the effluent to the farmer for a lump sum. No community charged a per unit price for the municipal sewage effluent to farmers. The city paid all operational and management costs; maintenance of irrigation equipment, however, was the farmer's responsibility in some agreements.

Land application treatment systems in Oklahoma generated benefits to both the farmer and the municipality. Farmers involved in land application systems obtained a more stable water source compared to dependence on rainfall. Municipal sewage effluent gave farmers another source of nitrogen, phosphorus, and potassium, and farmers were well aware of the production value of these nutrients. Both farmers and city officials responded that, with the addition of municipal wastewater, yields increased over those of dryland production (the previous method of production on nearly all the application sites), sometimes twofold. City officials in general felt that land application was a low cost handling method relative to available alternatives. A problem of handling a waste which needed to be disposed of was turned into a situation where a waste product was used and reclaimed. Concern with meeting federal and state regulations on handling municipal sewage effluent was a significant factor with many officials, so a feeling of operating the city's sewage effluent system "within the law" was a benefit to the city.

Certain problems occur with land application systems and proposed systems. The severity of the problems range from slight to severe. Seasonal supply fluctuations cause many land application systems to apply wastewater in winter when plants do not need it and to apply levels below plant needs in summer months due to short supply of effluent. Seepage and erosion in cell walls and dikes are significant concerns of city officials; either problem can seriously detract from successful operation of a land treatment facility and pose a risk of soil and groundwater contamination. A few cities have experienced the consequences of design errors which caused the land application system to be mismatched with the application site in any of a number of ways. Irrigation equipment has not functioned as intended in some systems. Bogging of irrigation equipment and tracking of the application site have caused problems. Some land application systems have experienced delays in startup due to equipment breakdown, seepage of effluent from lagoons, or miscalculation by the designers of the system.

A multiperiod linear programming model of an agricultural production component of a land application treatment system was developed; a similar model of a farm producing under dryland conditions also was constructed. An explanation of the structure of the models was presented in Chapter III. Coefficients for productivity, costs, and returns were taken from Oklahoma State University Enterprise Budgets. The model maximized the net present value of returns for the farmer, reflecting the hypothesis of the study which holds that emphasis on the farmer's objective of profit maximization and optimal agricultural production will increase the efficiency of use of municipal sewage effluent in Oklahoma land application systems. The model assumed that the municipal government and the farmer or landowner had an agreement on application of the municipal wastewater on the farmer's land for a period of 20 years. A discount rate of 6.0 percent was assumed for the planning horizon.

The farms illustrated by the linear programming models were representative farms for Oklahoma. The irrigated model represents a 240 acre farm incorporating irrigation of municipal sewage effluent into its production enterprises. The dryland model represents a farm identical to the one in the irrigated model except that it does not irrigate any tract of land with municipal sewage effluent or conventional irrigation water.

Three scenarios were tested by the linear programming models; production on 240 acres of farmland irrigated with municipal sewage effluent, dryland production on 240 acres of farmland, and production on 300 acres of land irrigated with municipal sewage effluent. Models of farms containing like acreages of irrigated and dryland production were compared and contrasted to measure the relative benefits of using municipal sewage effluent in crop or forage production enterprises. Irrigation of wastewater on 300 acres was designed to evaluate the worth of municipal sewage effluent as an input in a situation where an insufficient supply of water exists to enable irrigation of available acreage.

The 240 acre empirical model results showed that agricultural production with irrigation of municipal sewage effluent was more profitable and used more available acreage than production under dryland conditions over the 20 year period. The net present value of the 20 year income stream was $441,186.87 for the irrigated model and $82,512.00 for the dryland model. Annual income also was significantly greater for each year in the irrigated model.

The comparison of production with municipal sewage effluent irrigation with production under dryland conditions is valid in Oklahoma. This set of choices was shown by the survey of Oklahoma communities to exist. For this reason, no comparison between production with wastewater and production with conventional irrigation water was attempted.

A problem faced by many Oklahoma land application systems was exhibited in the pattern of effluent storage in the 240 acre irrigated model. The volume of wastewater to be stored usually exceeded the capacity of the holding cell from February through May in each year. This corresponded with the period of low demand for irrigation water and low net evapotranspiration. Holding pond overflow would result unless wastewater is applied during late fall and winter months, even though little or no crop demand for water existed from October through February.

The 300 acre irrigated model results provided values for municipal sewage effluent used as a production input. Shadow prices ranged from $2.13 per acre inch from January through September in year 1 to $0.69 per acre inch from January through September in year 20. The shadow price fluctuation, shown in Figure 2, is gradually downward.

Conclusions and Recommendations

Certain conclusions can be drawn about using municipal sewage effluent as a source of irrigation water for crops or forage in Oklahoma land application treatment systems. From the evidence presented in this study, the case can be made that the physical environment of the land application system needs control measures if the system is to succeed with respect to the goals of both the municipality and the farmer.

From the perspective of the farmer, municipal sewage effluent can be used in production of crops or forage in Oklahoma efficiently and profitably. Farmers can benefit from wastewater irrigation in several ways. In areas where water is scarce or not readily available in the form of conventional irrigation water, municipal sewage effluent can provide the water resource needed by crops. However, farmers who do not own land near the city or facility are at a distinct disadvantage in obtaining use of effluent due to prohibitive costs of transporting effluent to faraway farms. Nutrients such as nitrogen, phosphorus, and potassium are provided by municipal sewage effluent, either adding to or replacing chemical fertilizer applied by the farmer.

From the perspective of the municipal government, land application is still a viable treatment option when the farmer's goal of optimal agricultural production is respected. An agreement to use privately owned land as an application site would afford the city the flexibility to permit the farmer's goals because land acquisition costs would be greatly reduced.

There may be an increase in O&M costs in a given land application system relative to alternative treatment systems. This factor may be important to a city in considering land application, particularly since capital costs are, in effect, subsidized via construction cost share grants while O&M costs are not.

Pricing municipal sewage effluent according to its value in production of crops or forage may not work in Oklahoma communities at present. The nature of the city-farmer agreements in study are communities was in most cases either informal or simple exchange of wastewater for the right to apply effluent to a tract of land. A pay-as-you-go method of allocating wastewater, such as a per unit price, may become more suitable as more Oklahoma farmers become familiar with the option of effluent irrigation and agreements become more sophisticated.

The seasonality of water demand, along with the types of crops and forage grown in Oklahoma, may combine to make application of municipal sewage effluent in winter months necessary. Even though no water may be needed by plants during colder months, a water balance may not be attainable without such application of wastewater. Care should be exercised, though, when applying effluent in winter. Frozen soil will not allow wastewater to infiltrate, and temperatures around freezing could cause freezing of wastewater in pipes and subsequent pipe damage.

Two of the most important factors in the success of land application treatment systems with agricultural production components are system management and cooperation between city and farmer. Because the objectives of the city and the farmer in land application systems are often conflicting, the level of cooperation between the two parties can dictate how successful the system is. Each party needs to be aware of the objectives of the other to increase understanding on both sides.

The potential for operational and environmental problems in a given system illustrates the significance of proper management of the land application system. Timing of wastewater application is one of the most important aspects of system management, depending upon what site-specific factors are present. A host of potential hazards, such as surface runoff, insufficient infiltration and/or percolation, bogging or tracking of equipment, and pond overflow compel the city and the farmer to take an active role in planning the operation of the land application system.

Under conditions conducive to agricultural production, the potential exists for increased farmer willingness, or demand, to utilize municipal sewage effluent in production enterprises. The extent of this potential cannot be quantified by the methodology of this study. Further research into municipal sewage effluent use as a crop or forage input, with an emphasis on factor demand, may yield a measure of the potential for municipal wastewater irrigation. The demand for input characteristics as it pertains to municipal sewage effluent may be examined, and linear programming analysis may be used to test the implications derived by such examination.

Limitations

Certain limitations exist with respect to the methodology of the study. The extent to which the results of the study can be interpreted is governed by these limitations.

The applicability and usefulness of the linear programming model results depend to some extent on the output prices and yields used, on the operating capital assumptions, and on the agricultural production activities used. A possibility for further research would be to vary any of the above factors in the model, particularly yields and prices.

The issue of application of excess nitrogen, phosphorus, and potassium is not explored. Nitrogen and phosphorus were applied in the irrigation model at levels exceeding plant requirements. The impact of applying large quantities of those plant nutrients is not modeled into the linear programming model. Productivity increases attributable to the accumulative effects of additional nutrients in the soil may occur. Other elements in the soil, such as copper, zinc, and iron, may increase in availability and alter the productivity of the application site.

Productivity on the application site is assumed to be static. This may or may not be a realistic assumption. Long term effects of sewage effluent application on productivity via buildup of wastewater characteristics are not considered. Constant production of wheat on tract C in both models may lead to reduced productivity on that tract; weed control would be one of the problems of such constant cropping.

Enterprise budgets from different regions of Oklahoma were used in the linear programming models. Although most of the budgets were for the northwest, some budgets for the southwest had to be used due to lack of availability of those budgets for the northwest. The regional crossing of some model coefficients will not yield the most ideally comparable model results for the crops involved.

Certain types of data found in the OSU Enterprise Budgets, such as yield coefficients, are subject to change over time as technology changes. The enterprise budgets are updated periodically. However, some coefficients may not reflect current technological or agronomic conditions, due to the large number of budgets in the OSU Enterprise Budget system.

Irrigation of municipal sewage effluent was compared and contrasted with dryland production in the empirical models. A comparison of irrigation of municipal wastewater with irrigation of conventional water would yield a different type of results. Evaluation of the effects of plant nutrients and other municipal sewage effluent constituents on agricultural production could be obtained more directly.

The population of the hypothetical Oklahoma town is assumed to be static over the 20 year time period. Although this assumption is valid for many small rural communities where land application of municipal wastewater may be used, zero population growth over 20 years is unrealistic in some larger communities. Land application system expansion questions would need to be addressed in those municipalities, ideally in the system design stage.

SELECTED BIBLIOGRAPHY

Agrawal, R. C. and E. O. Heady. Operations Research Methods for Agricultural Decisions. Ames, Iowa: Iowa State University Press, 1972.

Baker, M. "Costs of Alternative Wastewater Treatment Systems." In: C. E. Young and D. J. Epp, eds., Wastewater Management in Rural Communities: A Socio-economic Perspective. Institute for Research on Land and Water Resources, The Pennsylvania State University Information Report 103.

Bishop, A. B., et al. Social, Economic, Environmental, and Technical Factors Influencing Water Reuse. Utah Water Research Laboratory, College of Engineering, Utah State University, December, 1973.

Cabbiness, S. G. and D. D. Badger. Estimating the Economic Value of Nutrients in Municipal Sewage Effluent Used for Irrigation at Pauls Valley, Oklahoma. Oklahoma Current Farm Economics, Vol. 53, No. 4, December, 1980.

Cabbiness, S. G. and D. D. Badger. Implications for Water Rights Users of Land Application of Treated Sewage Effluent: The North Canadian River Case. Department of Agricultural Economics, Oklahoma Agricultural Experiment Station, and Oklahoma Water Resources Research Institute, Oklahoma State University, AE 8167, June, 1981.

Carlson, G. A. and C. E. Young. Factors Affecting Adoption of Land Treatment of Municipal Wastewater. Water Resources Research, Vol. 11, No. 5, October, 1975.

Chiang, A. C. Fundamental Methods of Mathematical Economics, 2nd ed. McGraw-Hill, 1974.

Christensen, L. A. Irrigating with Municipal Effluent: A Socioeconomic Study of Community Experience. Natural Resource Economics Division, Economic Research Service, USDA, ERS-672, January, 1982.

Christensen, L. A., et al. Land Treatment of Municipal Wastewater: A Water Quality Option for Michigan Communities. Center for Rural Manpower and Public Affairs Report #41, Michigan State University, January, 1976.

Design Guidelines for Land Application of Municipal Wastewater. Water Quality Service, Oklahoma State Department of Health.

Donnermeyer, J. F. "Socio-cultural Factors Associated with the Utilization of Municipal Waste on Farmland for Agricultural Purposes." In: C. E. Young and D. J. Epp, eds., Wastewater Management in Rural Communities: A Socio-economic Perspective. Institute for Research on Land and Water Resources, The Pennsylvania State University Information Report 103.

Dorow, N. A. National Water Issues. Extension Service of Montana, Wyoming, North Dakota, and South Dakota, October, 1982.

Haith, D. A. and D. C. Chapman. "Land Application as a Best Practical Waste Treatment Alternative." In: R. C. Loehr, ed., Land as a Waste Management Alternative. Proceedings of the 1976 Cornell Agricultural Waste Management Conference. Ann Arbor Science Publishers, 1977.

Heady, E. O. Economics of Agricultural Production and Resource Use. New York: Prentice-Hall, 1952.

Henderson, J. M. and R. E. Quandt. Microeconomic Theory: A Mathematical Approach, 3rd ed. McGraw-Hill, 1980.

Jewell, W. J. and B. L. Seabrook. A History of Land Application as a Treatment Alternative. U.S. Environmental Protection Agency, MCD-40, April, 1979.

Jurgens, M. H. Animal Feeding and Nutrition, 4th ed. Dubuque, Iowa: Kendall/Hunt Publishing Company, 1978.

Kardos, L. T. A New Prospect. Environment. Vol. 12, No. 2, 1970.

Ladd, G. W. and M. B. Martin. Prices and Demands for Input Characteristics. American Journal of Agricultural Economics. Vol. 58, No. 1, February, 1976.

Lee, G. F. "Potential Problems of Land Application of Domestic Wastewaters." In: R. L. Sanks and T. Asano, eds., Land Treatment and Disposal of Municipal and Industrial Waterwater. Ann Arbor Science Publishers.

Massey, D. T. Features of Federal Law That Encourage Adoption of Land Application of Wastewater. Journal of Water Resources Planning and Management. Vol. 109, No. 2, April, 1983.

Moss, C. B. A Polyperiod Analysis of Financial Performance with Alternative Resource Endowments, Credit Restraints, and Organizational Forms. Unpublished M.S. thesis, Department of Agricultural Economics, Oklahoma State University, July, 1984.

Pettyjohn, W. A., H. White and S. Dunn. Water Atlas of Oklahoma. University Center for Water Research, Oklahoma State University, March, 1983.

Schwab, D. and J. Stiegler. Agricultural Use of Municipal/Industrial Wastewaters. OSU Extension Facts No. 1510, Cooperative Extension Service, Oklahoma State University, July, 1984.

Seitz, W. D and E. R. Swanson. "Economic Aspects of the Application of Municipal Wastes to Agricultural Land." In: Recycling Municipal Sludges and Effluents on Land. Proceedings of the Joint Conferences on Recycling Municipal Sludges and Effluents on Land, U.S. Environmental Protection Agency, USDA, and National Association of State Universities and Land-Grant Colleges, July 9-13, 1973.

Sullivan, R. H., M. M. Cohn and S. S. Baxter. Survey of Facilities Using Land Application of Wastewater. U.S. Environmental Protection Agency, EPA-430/9-73-006, July, 1973.

Tietjen, C. "The Admissible Rate of Waste (Residue) Application on Land With Regard to High Efficiency in Crop Production and Soil Pollution Abatement." In: R. C. Loehr, ed., Land as a Waste Management Alternative. Proceedings of the 1976 Cornell Agricultural Waste Management Conference. Ann Arbor Science Publishers, 1977.

Walker, J. M. Wastewater: Is Muskegon County's Solution Your Solution? U.S. Environmental Protection Agency, MCD-34, August, 1979.

Webb, A. and D. D. Badger. Environmental and Economic Aspects of Land Application of Municipal Effluents. Oklahoma Agricultural Experiment Station No. 3252, Oklahoma State University, November, 1976.

Wells, D. M., R. M. Sweazy and G. A. Whetstone. Long-term Experiences with Effluent Reuse. Journal of the Water Pollution Control Federation, Vol. 51, No. 11, November, 1979.

Williams, J. R., L. J. Connor and L. W. Libby. Case Studies and Comparative Cost Analyses of Land and Conventional Treatment of Wastewater by Small Municipalities in Michigan. Department of Agricultural Economics, Michigan State University Agricultural Economics Report # 329, October, 1977.

Young, C. E. The Cost of Land Application of Wastewater: A Simulation Analysis. Natural Resource Economics Division, Economics Research Service, USDA, Technical Bulletin No. 1555, November, 1976.

Young, C. E. Land Application of Wastewater: A Cost Analysis. Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, USDA, Technical Bulletin No. 1594, September, 1978.

Young, C. E. The Economics of Municipal Wastewater Reuse. Journal of the American Water Works Association. July, 1982.

APPENDIX A

SURVEY FORMS

Confidential

SURVEY
OF
MUNICIPAL OFFICIALS

ECONOMIC AND ENVIRONMENTAL IMPACTS OF INNOVATIVE
AND ALTERNATIVE METHODS OF SEWAGE EFFLUENT DISPOSAL

Department of Agricultural Economics
Oklahoma Agricultural Experiment Station
Oklahoma State University
Stillwater, Oklahoma 74078
Summer, 1984

I. GENERAL INFORMATION

1. Name of City or Town________________________
2. City Official Interviewed________________________
   Title____________
3. Mailing Address________________________
4. Most Recent Estimate of City Population____________
5. Number of People Served by Sewage Treatment Plant________
6. Total Daily Volume of Effluent Handled by City Sewage Plant
   ____
7. System of Disposal Used Previously________________
   ____

II. INNOVATIVE AND ALTERNATIVE TREATMENT (I&A) METHOD(S)

1. When Did City Apply to Oklahoma State Department of Health For I&A Method of Treating Effluent? __________(month and year)
2. When Did You Receive Approval To Use I&A Method of Disposal?
   ____________(month and year)
3. When Did You Begin Using I&A Method To Dispose of Effluent?
   ____________(month and year)
4. With Whom Do You Have Agreement To Dispose of Effluent, If Land Application Is Involved?____________________
   ________________________(Name and address)
5. Where Is This Land Located?____________________
   ____

Confidential

-2-

6. How Many Acres Are Involved?______________________
7. What Type of Irrigation System Is Involved?______________________

____

8. What Special Arrangements Were Made With The Landowner To Take The Effluent? ______________________
   Terms of Lease?______________________
   Money Exchanged?______________________
   O&M Costs Paid By City?______________________
   Water Rights Involved?______________________
   Storage Ponds Built?______________________
   Other?______________________

____

III. EPA CONSTRUCTION GRANT INFORMATION

1. When Did City Apply To EPA For A "Construction" Grant For I&A Treatment Method?______________________(month and year)
2. When Was The Grant Approved?______________________(month and year)
3. What Was The Total Cost?______________________
4. What Was Cost-Sharing Arrangement With EPA?______________________

____

5. When Was The I&A System Completed?______________________

IV. ECONOMIC AND SPECIAL INFORMATION

1. How Has The I&A System Worked?______________________

____

____

2. Have You Had Any Special Problems With The I&A System? (Such as Pond Overflow, Bogging Down of Equipment, Breakdown of Equipment, etc.)
   Yes___ No___ If Yes, Please Explain______________________

____

____

3. Did You Consider Other Alternatives To Land Treatment? Yes___ No___
   If So, What Were They?______________________

____

4. Land Treatment Costs Compared With Alternatives:

A. Higher	C. Lower	E. Similar
B. Much Higher	D. Much Lower	F. Not Sure

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5. What Recommendations Do You Have For Other Towns Who May Be Considering I&A Methods of Sewage Effluent Disposal?

DDB/mcb
May, 1984

CONFIDENTIAL CONFIDENTIAL

FARMERS SURVEY

ECONOMIC AND ENVIRONMENTAL IMPACTS OF INNOVATIVE AND ALTERNATIVE METHODS OF SEWAGE EFFLUENT DISPOSAL

Department of Agricultural Economics
Oklahoma State University
Stillwater, Oklahoma 74078
Summer, 1984

I. GENERAL INFORMATION

Name__________________________Address____________________________

Legal Description(or specific location)_____________________________

____

____

1. Acres operated on this farm:

_______________Acres owned _______________Acres rented out

_______________Acres rented in _______________Other

_______________Total acres

2. Tenancy (check one):

_________Full owner/operator ___________Tenant only

_________Part owner/operator ___________Landlord only

3. Operation (circle one or more)

a. Overall type

1. Cattle-grazing	8. Soybeans
2. Cattle & crops	9. Grain sorghum
3. Other grazing	10. Cotton
4. Dairy	11. Melons
5. Alfalfa	12. Peanuts
6. Wheat	13. Other
7. Other small grains	

b. Type of farm business organization (circle one)

1. Individual or family organization (not incorporated family farms)
2. Partnership
3. Family Corporation
4. Other

c. Age of operator

1. Under 25	4. 45-54
2. 25-34	5. 55-64
3. 35-44	6. 65 and over

d. Percent of family income that comes from the farm (circle one)

1. 100% 4. 40-59%
2. 80-90% 5. 20-39%
3. 60-79% 6. 0-19%

II. IRRIGATION INFORMATION

1. Number of acres of crops or pastures normally irrigated

Crop or Pasture	Acres Irrigated					
	1975	1980	1981	1982	1983	1984
____________	____	____	____	____	____	____
____________	____	____	____	____	____	____
____________	____	____	____	____	____	____
____________	____	____	____	____	____	____
____________	____	____	____	____	____	____
____________	____	____	____	____	____	____
____________	____	____	____	____	____	____
____________	____	____	____	____	____	____

2. Water Rights
   a. Number of Acre Feet applied for ______________________________
   b. When did you receive the water right? ____________________ year
   c. Have you been using the water each year since then? yes ____ no ____
      If no, what was the reason for non-use? ____________________
      ____
3. What is the source of water?
   Ground____________ Surface______________
4. Have you had problems in obtaining the water from this source (these sources) for irrigation? Yes___No___If yes, when? _______________
5. What were the circumstances? ______________________________
   ____
   ____
   ____
   ____
6. Do you need more water than what your present permit(s) allows?
   Yes___No___ If yes, how many more acre feet per year do you need?
   _____________feet

III. USE OF MUNICIPAL SEWAGE EFFLUENT

1. When did you make an agreement to take the municipal sewage effluent?
   ______________________ month and year
2. What were the terms of the agreement?
   a. Length of agreement (number of years)____________________
   b. Number of acres involved____________________
   c. Soil type of the land____________________
   d. Crops or pastures grown on this land____________________
   e. Amount of water applied__________acre inches per application
   f. Total volume of water involved per year____________________
   g. Storage pond built? Yes___No___ Size:____________________

IV. ECONOMIC ASPECTS

1. What is the economic impact of the effluent in your production?
   a. Increase in yields/acre (or loss when water is not available)
      __________(how much)__________(crop)
      __________(how much)__________(crop)
      __________(how much)__________(crop)
      __________(how much)__________(crop)

2. What adjustments do you make in your farming operations if and when the effluent is not available on a reliable basis when needed for irrigation?

   ____
   ____
   ____
   ____
   ____

3. Are you able to maintain the same level of farm production when these adjustments are made? Yes___No___. Please explain.

   ____
   ____
   ____
   ____
   ____
   ____

4. What are your future plans for your farm operations if the effluent is no longer available, and/or is no longer economically feasible to pump?

____

____

____

____

5. Have you had any special problems in using the effluent? Yes__ No__
If yes, please explain.____

____

____

____

____

6. Do you have any recommendations for other farmers who may be planning to work with a city in using municipal sewage effluent on their land?

____

____

____

____

DDB/mcb
May, 1984

APPENDIX B

ENTERPRISE BUDGETS FOR LINEAR PROGRAMMING MODEL PRODUCTION ACTIVITIES

ALFALFA HAY, IRRIGATED, SURFACE SYSTEM — 81101291
33" WATER, OWNED HARVEST EQUIPMENT, CONVENTIONAL BALE — 01/02/84
NATURAL GAS @ $3 CO./MCF — NORTHWEST

OPERATING INPUTS	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
1/5 EST. COST	ACRE	130.000	0 200	38.00	
INSECTICIDE	ACRE	6.500	0.330	2.14	
PHOSPH (P2O5)	LBS.	0.290	100.000	29.00	
INSECTICIDE	ACRE	13.500	1.000	13.50	
RNTFERTSPRD/ACRE	ACRE	1.000	1.000	1.00	
ANNUAL OPERATING CAPITAL	DOL	0.150	14.715	2.21	
LABOR CHARGES	HR.	4.250	11.065	47.03	
MACHINERY FUEL, LUBE, REPAIRS	ACRE			61.06	
IRRIGATION FUEL, LUBE, REPAIRS	ACRE			90.09	
TOTAL OPERATING COST				284.03	

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 15.0%	DOL.	53.087	
DEPR., TAXES, INSUR.	DOL.	57.162	
IRRIGATION			
INTEREST AT 15 0%	DOL.	25.740	
DEPR., TAXES, INSUR.	DOL.	22.110	
LAND			
INTEREST AT 0.0%	DOL.	0.000	
TAXES	DOL.	0.000	
TOTAL FIXED COSTS		158 10	

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
ALFALFA HAY	TONS	75.000	6.500	487.50	
RETURNS ABOVE TOTAL OPERATING COSTS				203.47	
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD, RISK AND MANAGEMENT				45.37	

SURFACE SYSTEM, ASSUME ALL HAY EQUIPMENT IS OWNED. — GRIFFITH
WELL DEPTH-480, DEPTH TO WATER LEVEL-360, GALLONS PER MINUTE-850
LIGHT INDUSTRIAL ENGINE-225 HP ALUM. — 12/09/83 — 1000000000

PROCESSED BY DEPT OF AGRI. ECON. - OKLAHOMA STATE UNIVERSITY
PROGRAM DEVELOPED BY DEPT. OF AGRI ECON. OKLAHOMA STATE UNIVERSITY

RETURNS ABOVE TOTAL OPERATING COSTS
WHEN THE QUANTITY OF ALFALFA HAY RANGES FROM 5.50 TO 7 50
AND THE PRICE OF ALFALFA HAY RANGES FROM 65 00 TO 85.00

QUANTITY OF ALFALFA HAY

PRICE OF ALFALFA HAY	5.50	6.00	6.50	7.00	7.50
65 00	73.47	105 97	138 47	170.97	203 47
70.00	100.97	135.97	170.97	205.97	240 97
75.00	128.47	165.97	203.47	240.97	278 47
80.00	155 97	195.97	235 97	275.97	315 97
85.00	183 47	225 97	268 47	310 97	353 47

RETURNS NOT ADJUSTED FOR EFFECT OF YIELD CHANGES ON COSTS

BUDGET IDENTIFICATION NUMBER 81101291011511 ANNUAL CAPITAL MONTH 6 BUDGET RECORD NUMBER 59
BUDGET FILE 1

ALFALFA HAY IRRIGATED, SURFACE SYSTEM 81101291
33" WATER OWNED HARVEST EQUIPMENT CONVENTIONAL BALE 01/02/84
NATURAL GAS @ $3 00/MCF NORTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SEP	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 ALFALFA HAY	0.00	0 00	0.00	0.00	0.00	1 70	1 60	1 60	1 60	0.00	0 00	0.00	-1 000	0 000	3	81.	2.	0
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 1/5 EST. COST	0.00	0 00	0 00	0 00	0.00	0.00	0 00	0 00	0 20	0 00	0.00	0 00	190 000	0 000	7	299	3	0.
12 INSECTICIDE	0 00	0 00	0 00	0 33	0.00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	6.500	0 000	7	240	3	0
15 PHOSPH (P2O5)	0 00	0 00	100 00	0.00	0.00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	-1 000	0 000	12	214	3	0
16 INSECTICIDE	0 00	0 00	0 00	0 00	1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	13 500	0 000	7	240	3	0
21 RNTFERTSPRD/ACRE	0 00	0.00	1 00	0.00	0.00	0.00	0.00	0 00	0 00	0 00	0 00	0 00	-1 000	0 000	7	362	3.	0
MACHINERY REQUIREMENTS						TIMES OVER							XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
38 TRACTOR(3)	0 00	0 00	1 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0 000	0 000	3.	3	4	0
39 PTO MOWER - COND	0.00	0 00	0 00	0 00	0 00	1 00	1 00	1 00	1 00	0 00	0 00	0 00	0 000	0 000	3	88	4	0
40 PTO BALER - M D	0 00	0 00	0 00	0 00	0 00	1 00	1 00	1 00	1 00	0 00	0 00	0 00	0 000	0 000	3.	90	4	0
41 PTO BALE WAGON	0.00	0 00	0 00	0.00	0 00	1.00	1.00	1 00	1 00	0 00	0.00	0.00	0 000	0 000	3	92	4	0.
48 ACIN IRRIG WATER	0.00	0 00	0.00	6 00	3.00	4 00	8 00	8.00	4.00	0 00	0.00	0 00						

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0.00	0.00	0 00	0 00	0 00	127 50	120 00	120 00	120 00	0 00	0 00	0 00	487 50
TOTAL EXPENSES	ACRE	0 00	0 00	39 28	18 52	21 69	23 87	34 79	34 79	61 87	0 00	0 00	0 00	234 80
RETURNS TO LAND, LABOR, CAPITAL, MACHINERY, OVERHEAD RISK AND MANAGEMENT														252 70
ANNUAL CAPITAL	DOL.	0 00	0.00	3 27	4 82	6 62	0 00	0 00	0.00	0.00	0 00	0 00	0 00	14 71
LABOR REQUIREMENTS BY MONTH														
MACHINERY LABOR	HR	0.00	0 00	1 21	0 00	0 00	0.86	0 86	0.86	0 86	0 00	0 00	0 00	4 63
IRRIGATION LABOR	HR	0.00	0 00	0.00	1 17	0 58	0 78	1 56	1 56	0 78	0 00	0 00	0 00	6 43
TOTAL LABOR	HR	0 00	0 00	1 21	1 17	0 58	1 64	2 42	2 42	1 64	0 00	0 00	0 00	11 07
IRRIGATION WATER	INCH	0 00	0 00	0 00	6 00	3.00	4 00	8 00	8 00	4 00	0 00	0 00	0 00	33 00

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR	TAX	TOTAL FIXED	REPAIR	FUEL	LUB	TOTAL VARIABLE	INT	HR/TIME
TRACTOR(3)	3	3 72	0 20	0 53	4 45	2.09	5 52	0 83	8 44	5 12	1 00
PTO MOWER - COND	88	13 57	0.50	1 38	15.44	9 61	0 00	0 00	9 61	12 49	0 21
PTO BALER - M D	90	7 89	0 29	0 80	8 98	2 58	0 00	0 00	2 58	7 26	0 21
PTO BALE WAGON	92	13 55	0 51	1 40	15 46	13 08	0 00	0 00	13 08	12 87	0 23

OPERATION	ITEM NO	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL.OIL.LUB. REPAIR PER ACRE	FIXED COSTS PER ACRE
PTO MOWER - COND	3.88	JUL	1 00	0 251	0 208	3 92	7 98
PTO BALER - M D	3.90	JUL	1 00	0 248	0 205	2 43	5 50
PTO BALE WAGON	3.92	JUL	1 00	0 357	0.295	6 59	11 45
PTO MOWER - COND	3.88	AUG	1 00	0.251	0 208	3 92	7.98
PTO BALER - M D.	3.90	AUG	1 00	0 248	0.205	2.43	5 50
PTO BALE WAGON	3.92	AUG	1 00	0.357	0 295	6 59	11 45
PTO MOWER - COND	3.88	SEP	1 00	0.251	0 208	3 92	7 98
PTO BALER - M D	3.90	SEP	1.00	0 248	0 205	2 43	5 50
PTO BALE WAGON	3.92	SEP	1 00	0.357	0.295	6 59	11 45
TRACTOR(3)	3. 3	MAR	1 00	1 200	1 100	9 28	10 53
PTO MOWER - COND	3 88	JUN	1 00	0 251	0 208	3 92	7 98
PTO BALER - M D	3 90	JUN	1 00	0 248	0 205	2 43	5 50
PTO BALE WAGON	3.92	JUN	1 00	0 357	0 295	6 59	11 45
TOTAL				4 624	3 930	61 06	*****

COLUMN / NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFIC-ENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	13 PURCHASE PRICE	14 FUEL TYPE	15 HOURS OF LIFE	16 HP
TRACTOR(3)	3.	100 0	31640	4.5	0 88	1.20	0 000631	1 60	600	10 0	0 650	0 920	31640	3	12000	100
PTO MOWER - COND	88	12 0	11000	4 3	0 77	1 00	0 002510	1 30	80	8 0	0 560	0 885	11000	0	1000	0
PTO BALER - M D	90	20.0	8000	3 0	0 67	0 85	0 002510	1 30	100	8 0	0 560	0 885	8000	0	2000	0
PTO BALE WAGON	92	14 0	14000	5.0	0 40	1 00	0 002510	1 30	100	8 0	0.600	0 885	14000	0	1000	0

SURFACE SYSTEM ASSUME ALL HAY EQUIPMENT IS OWNED GRIFFITH MACHINERY COMPLEMENT 11
WELL DEPTH-480 DEPTH TO WATER LEVEL-360 GALLONS PER MINUTE-850 EQUIPMENT COMPLEMENT 11
LIGHT INDUSTRIAL ENGINE-225 HP ALUM 12/09/83 1000000000 PRICE VECTOR 1

	LINE	CHANGE	LINE	CHANGE	LINE	CHANGE	LINE	CHANGE	LINE	CHANGE
GENERAL NAME CHANGE-->	298	1/5 EST COST	361	SPREADER RENTAL						

	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE
PARAMETER CHGS-->	18	0 194872										
IRRIGATION------>		5 000	0 630	0 780	0 030	0 010	1 450	0 440	1 890	0 300		3 510

GRAIN SORGHUM, IRRIGATED, CIRCULAR SPRINKLER 73100967
24" WATER, CUSTOM HARVEST 01/02/84
NATURAL GAS @ $3.00/MCF NORTHWEST

OPERATING INPUTS:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
GRAIN SORG SEED	LBS.	0.750	8.000	6.00	
NITROGEN (N)	LBS.	0.330	70.000	23 10	
NITROGEN (N)	LBS.	0.330	60.000	19 80	
PHOSPH (P2O5)	LBS.	0.290	50.000	14.50	
HERBICIDE	ACRE	9.000	1.000	9.00	
INSECTICIDE	ACRE	6.500	1.000	6.50	
CUSTOM COMBINE	CWT.	0.330	56.000	18.48	
RNTFERTSPRD/ACRE	ACRE	1.000	1.000	1.00	
ANNUAL OPERATING CAPITAL	DOL.	0.150	61.526	9.23	
LABOR CHARGES	HR.	4.250	2.335	9 92	
MACHINERY FUEL, LUBE, REPAIRS	ACRE			12.67	
IRRIGATION FUEL, LUBE, REPAIRS	ACRE			99.12	
TOTAL OPERATING COST				229.32	

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 15.0%	DOL.	10.419	
DEPR., TAXES, INSUR.	DOL.	10.155	
IRRIGATION			
INTEREST AT 15.0%	DOL.	51.600	
DEPR., TAXES, INSUR.	DOL.	41.280	
LAND			
INTEREST AT 0.0%	DOL.	0.000	
TAXES	DOL.	0.000	
TOTAL FIXED COSTS		113.45	

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
GRAIN SORGHUM	CWT.	4.600	56.000	257.60	
PASTURE	AUMS	0.000	1.400	0.00	
TOTAL RECEIPTS				257 60	
RETURNS ABOVE TOTAL OPERATING COSTS				28 28	
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD, RISK AND MANAGEMENT				-85.17	

CIRCULAR SPRINKLER IRRIGATION SYSTEM GRIFFITH
480 FT. WELL, 360 FT LIFT, 850 G P.M LIGHT INDUSTRIAL
CUSTOM COMBINE COST INCLUDES HAULING 12/09/83 1000000000

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PROGRAM DEVELOPED BY DEPT. OF AGRI ECON. OKLAHOMA STATE UNIVERSITY

RETURNS ABOVE TOTAL OPERATING COSTS
WHEN THE QUANTITY OF GRAIN SORGHUM RANGES FROM 52 00 TO 60.00
AND THE PRICE OF GRAIN SORGHUM RANGES FROM 4.10 TO 5.10

		QUANTITY OF GRAIN SORGHUM				
		52.00	54.00	56.00	58.00	60 00
	4.10	-14 80	-7.26	0.28	7 82	15 36
	4 35	-1 80	6 24	14 28	22 32	30 36
PRICE OF GRAIN SORGHUM	4 60	11 20	19.74	28 28	36 82	45 36
	4 85	24.20	33.24	42.28	51.32	60.36
	5.10	37 20	46.74	56.28	65 82	75 36

RETURNS NOT ADJUSTED FOR EFFECT OF YIELD CHANGES ON COSTS

BUDGET IDENTIFICATION NUMBER 731009670114111 ANNUAL CAPITAL MONTH 10 BUDGET RECORD NUMBER 68
BUDGET FILE 1

GRAIN SORGHUM IRRIGATED, CIRCULAR SPRINKLER 73100967
24" WATER, CUSTOM HARVEST 01/03/84
NATURAL GAS @ $3 00/MCF NORTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SEP	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 GRAIN SORGHUM	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0.00	56 00	0 00	0 00	-1 000	0 000	16	73	2	0
2 PASTURE	0 40	0 00	0 00	0 00	0.00	0.00	0 00	0 00	0.00	0 00	0 50	0.50	0 000	0.000	10	150	2	0
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 GRAIN SORG SEED	0 00	0 00	0.00	0 00	0.00	8 00	0 00	0 00	0 00	0 00	0.00	0 00	-1 000	0 000	12	173	3	0
12 NITROGEN (N)	0.00	0 00	0.00	0 00	70 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	-1 000	0 000	12.	211	3	0.
13 NITROGEN (N)	0 00	0 00	0 00	0 00	0 00	0 00	30 00	30 00	0 00	0.00	0 00	0 00	-1 000	0.000	12	211	3.	0
14 PHOSPH (P2O5)	0 00	0 00	0.00	0 00	50 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-1 000	0 000	12	214	3	0
15 HERBICIDE	0 00	0 00	0 00	0 00	1 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	9 000	1 000	7	250	3	0.
16 INSECTICIDE	0 00	0 00	0 00	0 00	0 00	0 00	1 00	0.00	0 00	0 00	0 00	0 00	6.500	0 000	7	240	3	0
18 CUSTOM COMBINE	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	56 00	0 00	0 00	0 330	0 000	16.	305	3.	0
20 RNTFERTSPRD/ACRE	0 00	0 00	0 00	0.00	1 00	0 00	0.00	0.00	0.00	0 00	0 00	0.00	-1 000	0 000	7	362	3.	0
MACHINERY REQUIREMENTS					TIMES OVER								XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
37 SPIKE HARROW	0 00	0 00	0 00	0 00	1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 000	0 000	4	52	4	0
38 STALK SHREDDER	0 00	1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 000	0 000	4	74	4	0
39 OFFSET DISK	0 00	0 00	1 00	0.00	1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 000	0 000	4	38	4	0
40 CHISEL	0.00	0 00	1 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 000	0 000	4	45.	4	0.
45 PLANTER	0 00	0.00	0 00	0 00	0 00	1 00	0 00	0.00	0 00	0 00	0 00	0 00	0 000	0 000	4	62	4	0
46 ROTARY HOE	0 00	0 00	0 00	0 00	0 00	0 00	1 00	0 00	0.00	0.00	0 00	0 00	0 000	0 000	4	53	4.	0.
49 ACIN IRRIG WATER	0 00	0 00	0.00	0.00	6 00	3.60	7 20	7 20	0 00	0 00	0 00	0.00						

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	257 60	0 00	0 00	257 60
TOTAL EXPENSES	ACRE	0 00	3 31	3 28	0 00	75 24	22 71	47 51	39 64	0 00	18 48	0 00	0 00	210 17
RETURNS TO LAND, LABOR, CAPITAL, MACHINERY, OVERHEAD RISK, AND MANAGEMENT														47 43
ANNUAL CAPITAL	DOL	0 00	0 28	0 55	0.55	6 82	8.71	12 67	15 97	15 97	0 00	0 00	0 00	61 53

LABOR REQUIREMENTS BY MONTH

MACHINERY LABOR	HR	0 00	0 19	0 30	0 00	0 27	0 15	0 13	0 00	0 00	0 00	0 00	0 00	1 04
IRRIGATION LABOR	HR	0 00	0 00	0.00	0 00	0 32	0 19	0 39	0.39	0 00	0 00	0 00	0 00	1 29
TOTAL LABOR	HR	0 00	0 19	0 30	0.00	0 60	0 34	0 52	0.39	0 00	0 00	0 00	0 00	2 33
IRRIGATION WATER	INCH	0 00	0 00	0 00	0 00	6 00	3 60	7 20	7 20	0 00	0 00	0 00	0 00	24 00

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR	TAX	TOTAL FIXED	REPAIR	FUEL	LUB	TOTAL VARIABLE	INT	HR/TIME
TRACTOR(4)	4	4 50	0.25	0 64	5 38	2 53	6.90	1 03	10 46	6 20	1 00
SPIKE HARROW	52	1 01	0 04	0 12	1 17	0.23	0 00	0.00	0.23	1 08	0 11
STALK SHREDDER	74	5.43	0 20	0 55	6 18	9 25	0 00	0 00	9 25	4 99	0 16
OFFSET DISK	38	4 28	0 18	0 52	4 98	2 01	0 00	0 00	2 01	4 59	0 12
CHISEL	45	5 60	0 24	0 68	6 52	1 90	0 00	0 00	1 90	6 00	0 13
PLANTER	62	10 70	0 46	1 30	12.46	3 43	0.00	0 00	3 43	11 47	0 12
ROTARY HOE	53	3.29	0.14	0.40	3 83	1 15	0 00	0 00	1 15	3 53	0 11

OPERATION	ITEM NO.	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL.OIL LUB , REPAIR PER ACRE	FIXED COSTS PER ACRE
STALK SHREDDER	4.74	FEB	1 00	0 133	0 160	3.31	3 82
OFFSET DISK	4 38	MAR	1 00	0 139	0 115	1 56	2 57
CHISEL	4.45	MAR	1 00	0 156	0 125	1 73	3.26
SPIKE HARROW	4 52	MAY	1 00	0 135	0 111	1 30	1 67
OFFSET DISK	4.38	MAY	1 00	0 139	0 115	1 56	2 57
PLANTER	4.62	JUN	1 00	0 149	0 123	1 84	4 32
ROTARY HOE	4.53	JUL	1 00	0.131	0 109	1 37	2 18
TOTAL				1 042	0 861	12 67	20 57

COLUMN NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFIC-ENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	13 PURCHASE PRICE	14 FUEL TYPE	15 HOURS OF LIFE	16 HP
TRACTOR(4)	4	125 0	38300	4 5	0 88	1 20	0 000631	1 60	600	10 0	0 680	0 920	38300	3	12000	125
OFFSET DISK	38	18 0	7800	4 8	0 83	0 65	0 000251	1 80	150	10 0	0 600	0 885	7800	0	2000	0
CHISEL	45	20 0	8500	4 0	0 80	0 65	0 000251	1 80	125	10 0	0 600	0 885	8500	0	2000	0
SPIKE HARROW	52	20.0	1225	5 3	0 70	0 65	0 000251	1 80	100	10 0	0 600	0 885	1225	0	2000	0
ROTARY HOE	53	20 0	4000	5 0	0 76	1 00	0 000251	1 80	100	10 0	0 600	0 885	4000	0	2000	0
PLANTER	62	20 0	7800	5 0	0 67	0 80	0 000631	1 60	60	10 0	0 600	0 885	7800	0	1200	0
STALK SHREDDER	74	13 3	5500	4 8	0 81	1 80	0 002510	1 30	100	8 0	0 560	0 885	5500	0	1000	0

CIRCULAR SPRINKLER IRRIGATION SYSTEM GRIFFITH MACHINERY COMPLEMENT 11
480 FT WELL 360 FT LIFT 850 G P M LIGHT INDUSTRIAL EQUIPMENT COMPLEMENT 11
CUSTOM COMBINE COST INCLUDES HAULING 12/08/83 1000000000 PRICE VECTOR 1

NO NAME CHANGES HAVE BEEN STORED WITH THIS BUDGET

	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE
PARAMETER CHGS-->	18	0 053846										
IRRIGATION------>		4 000	1 800	2 150	0 080	0 040	3 870	1 060	2 870	0 400		4 350

BERMUDA IRRIGATED, WELL SOURCE	83688301
WELL SOURCE	01/02/84
SPRINKLER IRRIGATED	SOUTHWEST

OPERATING INPUTS	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
BERMUDA EST.	ACRE	180.000	0.100	18 00	________
NITROGEN (N)	LBS.	0.290	200.000	58.00	________
PHOSPH (P205)	LBS.	0.320	40.000	12.80	________
IRRIGATION COSTS	ACRE	66.000	1.000	66.00	________
ANNUAL OPERATING CAPITAL	DOL.	0.150	77.915	11.69	________
LABOR CHARGES	HR.	4.250	1 660	7.06	________
MACHINERY FUEL, LUBE, REPAIRS	ACRE			0.58	________
TOTAL OPERATING COST				174.13	________

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 15.0%	DOL.	0.347	________
DEPR., TAXES, INSUR.	DOL.	0.302	________
LAND			
INTEREST AT 0.0%	DOL.	0.000	________
TAXES	DOL.	0.000	________
TOTAL FIXED COSTS		0.65	________

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PASTURE	AUMS	0 000	8.800	0.00	________
RETURNS ABOVE TOTAL OPERATING COSTS				-174 13	________
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD, RISK AND MANAGEMENT				-174.78	________

$60 PER ACRE TO ESTABLISH   PROVENCE
PRO-RATED OVER 10 YEARS

12/08/83   0000110000

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PROGRAM DEVELOPED BY DEPT. OF AGRI. ECON. OKLAHOMA STATE UNIVERSITY

BUDGET IDENTIFICATION NUMBER 836883010 606 6   ANNUAL CAPITAL MONTH 5   BUDGET RECORD NUMBER 293
BUDGET FILE 1

BERMUDA IRRIGATED, WELL SOURCE	83688301
WELL SOURCE	01/02/84
SPRINKLER IRRIGATED	SOUTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SEP	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 PASTURE	0 00	0.00	0 00	0.30	2.00	2 00	2 00	1 00	1 00	0 50	0 00	0 00	0 000	0 000	10	150	2.	0
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 BERMUDA EST	0 10	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	180 000	0 000	7	183	3	0
12 NITROGEN (N)	0 00	0 00	0 00	100 00	0 00	100 00	0 00	0 00	0 00	0 00	0 00	0 00	-1 000	0 000	12	211	3	0
13 PHOSPH (P205)	0 00	0 00	0 00	40 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-1 000	0 000	12	214	3	0.
14 IRRIGATION COSTS	0 00	0 00	0 00	0 00	0.20	0.20	0 20	0 20	0.20	0 00	0 00	0 00	66 000	0 000	7	419	3	0
MACHINERY REQUIREMENTS						TIMES OVER							XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
38 TRACTOR(3)	0.00	0.00	0 00	0 05	0 00	0.00	0 00	0.00	0 00	0 00	0.00	0 00	0.000	0 000	0	3	4	0
49 ACIN IRRIG WATER	0 00	0.00	0 00	0.00	4 00	8 00	8 00	8 00	4 00	0 00	0 00	0 00						
50 OTHER LABOR	0 00	0 00	0 00	0 00	0 20	0 40	0 40	0 40	0 20	0 00	0 00	0 00						

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
TOTAL EXPENSES	ACRE	18 00	0 00	0 00	42 38	13 20	42 20	13 20	13 20	13 20	0 00	0 00	0 00	155 38
RETURNS TO LAND, LABOR, CAPITAL, MACHINERY, OVERHEAD, RISK, AND MANAGEMENT														-155 38
ANNUAL CAPITAL	DOL	8 32	8 32	8 32	11 85	0 00	3 52	4 62	5 72	6 82	6 82	6 82	6 32	77 32

LABOR REQUIREMENTS BY MONTH

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MACHINERY LABOR	HR	0 00	0 00	0 00	0 06	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 06
OTHER LABOR	HR.	0 00	0 00	0 00	0 00	0 20	0 40	0 40	0 40	0.20	0 00	0 00	0 00	1 60
TOTAL LABOR	HR	0 00	0 00	0 00	0 06	0 20	0 40	0 40	0 40	0 20	0 00	0 00	0 00	1 66

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR	TAX	TOTAL FIXED	REPAIR	FUEL	LUB	TOTAL VARIABLE	INT	HR/TIME
TRACTOR(3)	3	4 58	0 25	0 65	5 48	2 68	6 90	1·03	10 62	6 31	1 00

OPERATION	ITEM NO	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL OIL LUB REPAIR PER ACRE	FIXED COSTS PER ACRE
TRACTOR(3)	3	APR	0 05	0 060	0 055	0 58	0 65
TOTAL				0 060	0 055	0 58	0 65

COLUMN NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFICIENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	13 PURCHASE PRICE	14 FUEL TYPE	15 HOURS OF LIFE	16 HP
TRACTOR(3)	3.	125 0	35000	4 5	0 88	1 25	0 000631	1 60	600	10 0	0 680	0 920	39000	3	12000	125

$60 PER ACRE TO ESTABLISH   PROVENCE   MACHINERY COMPLEMENT 6
PRO-RATED OVER 10 YEARS   EQUIPMENT COMPLEMENT 6
12/08/83   0000110000   PRICE VECTOR 6

	LINE	CHANGE	LINE	CHANGE	LINE	CHANGE	LINE	CHANGE	LINE	CHANGE
GENERAL NAME CHANGE->	183	BERMUDA EST	419	IRRIGATION COSTS						

NO COMPLEMENT CHANGES HAVE BEEN STORED WITH THIS BUDGET

IRRIGATED WHEAT 18" WATER — 76101857
CIRCULAR SPRINKLER SYSTEM, NATURAL GAS — 08/01/83
CUSTOM HARVEST — NORTHWEST

OPERATING INPUTS.	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
WHEAT SEED	BU.	4 250	1.000	4 25	
NITROGEN (N)	LBS	0.330	65.000	21.45	
NITROGEN (N)	LBS.	0.330	50 000	16 50	
PHOSPH (P2O5)	LBS.	0 290	40.000	11 60	
CROP INSURANCE	DOL.	0.140	24 750	3 46	
CUSTOM COMBINE	ACRE	12.000	1.000	12.00	
CUSTOM COMBINE	BU.	0.120	35.000	4 20	
CUSTOM HAULING	BU.	0.220	55.000	12.10	
RNTFERTSPRD/ACRE	ACRE	1.000	1.000	1.00	
2-4-D	ACRE	1 700	1.000	1.70	
ANNUAL OPERATING CAPITAL	DOL.	0.140	67.565	9.46	
LABOR CHARGES	HR	4.250	1 927	8.19	
MACHINERY FUEL, LUBE, REPAIRS	ACRE			8.57	
IRRIGATION FUEL, LUBE, REPAIRS	ACRE			77.58	
TOTAL OPERATING COST				192.07	

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 14 0%	DOL	7 442	
DEPR., TAXES, INSUR	DOL	7 776	
IRRIGATION			
INTEREST AT 14.0%	DOL.	42.480	
DEPR, TAXES, INSUR.	DOL.	40.140	
LAND			
INTEREST AT 0.0%	DOL.	0.0	
TAXES	DOL.	0.0	
TOTAL FIXED COSTS		97 84	

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
WHEAT	BU.	3.700	55 000	203 50	
S.G. PASTURE	AUMS	0.0	1.000	0.0	
TOTAL RECEIPTS				203 50	
RETURNS ABOVE TOTAL OPERATING COSTS				11.43	
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD, RISK AND MANAGEMENT				-86.41	

CIRCULAR SPRINKLER SYSTEM — HININGER
WELL DEPTH-480, DEPTH TO WATER LEVEL-360, GALLONS PER MINUTE-850
LIGHT INDUSTRIAL ENGINE-225 HP, NATURAL GAS — 05/31/83 — 1000000000

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PROGRAM DEVELOPED BY DEPT OF AGRI. ECON. OKLAHOMA STATE UNIVERSITY

RETURNS ABOVE TOTAL OPERATING COSTS
WHEN THE QUANTITY OF WHEAT RANGES FROM 45 00 TO 65 00
AND THE PRICE OF WHEAT RANGES FROM 3 20 TO 4 20

PRICE OF WHEAT	QUANTITY OF WHEAT: 45.00	50 00	55 00	60.00	65 00
3 20	-45 87	-30 97	-16 07	-1 17	13 73
3 45	-34.62	-18.47	-2 32	13 83	29.98
3.70	-23 37	-5 97	11 43	28 83	46 23
3.95	-12 12	6.53	25 18	43 83	62.48
4 20	-0.87	19 03	38 93	58 83	78 73

RETURNS NOT ADJUSTED FOR EFFECT OF YIELD CHANGES ON COSTS

BUDGET IDENTIFICATION NUMBER 76101857011411 ANNUAL CAPITAL MONTH 6 BUDGET RECORD NUMBER 115
BUDGET FILE 1

IRRIGATED WHEAT 18" WATER
CIRCULAR SPRINKLER SYSTEM NATURAL GAS
CUSTOM HARVEST

76101857
08/01/83
NORTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SEP	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 WHEAT	0 0	0 0	0 0	0 0	0 0	55 00	0 0	0 0	0 0	0 0	0 0	0 0	-1 000	0 0	2	76	2	0
2 S G PASTURE	0 20	0 20	0 20	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 20	0 20	-1 000	0 0	10	153	2	0
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 WHEAT SEED	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 00	0 0	0 0	0 0	-1 000	0 0	2	176	3	0
12 NITROGEN (N)	0 0	0 0	0 0	0 0	0 0	0 0	0 0	65 00	0 0	0 0	0 0	0 0	-1 000	0 0	12	211	3	0
13 NITROGEN (N)	0 0	25 00	25 00	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	-1 000	0 0	12	211	3	0
14 PHOSPH (P205)	0 0	0 0	0 0	0 0	0 0	0 0	0 0	40 00	0 0	0 0	0 0	0 0	-1 000	0 0	12	214	3	0
15 CROP INSURANCE	0 0	0 0	0 0	33 00	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 140	0 750	15	452	3	0
16 CUSTOM COMBINE	0 0	0 0	0 0	0 0	0 0	1 00	0 0	0 0	0 0	0 0	0 0	0 0	12 000	0 0	7	305	3	0
17 CUSTOM COMBINE	0 0	0 0	0 0	0 0	0 0	35 00	0 0	0 0	0 0	0 0	0 0	0 0	0 120	0 0	2	305	3	0
18 CUSTOM HAULING	0 0	0 0	0 0	0 0	0 0	55 00	0 0	0 0	0 0	0 0	0 0	0 0	0 220	0 0	2	306	3	0
19 RNTFERTSPRD/ACRE	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 00	0 0	0 0	0 0	0 0	-1 000	0 0	7	362	3	0
20 2-4-D	0 50	0 50	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 700	1 000	7	251	3	0
MACHINERY REQUIREMENTS						TIMES OVER							XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
38 OFFSET DISK	0 0	0 0	0 0	0 0	0 0	1 00	0 0	1 00	0 0	0 0	0 0	0 0	0 0	0 0	4	37	4	0
39 SWEEP	0 0	0 0	0 0	0 0	0 0	0 0	1 00	0 0	0 0	0 0	0 0	0 0	0 0	0 0	4	41	4	0
42 DRILL WO/FERT	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 50	0 0	0 0	0 0	0 0	0 0	4	57	4	0
43 DRILL WO/FERT	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 50	0 0	0 0	0 0	0 0	0 0	0	57	4	0
44 SPRAYER	0 50	0 50	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	4	68	4	0
45 DRY FERT SPREAD	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 00	0 0	0 0	0 0	0 0	0 0	0 0	2	71	4	0
46 PICKUP	0 0	0 05	0 0	0 0	0 0	0 05	0 0	0 05	0 0	0 0	0 0	0 0	0 0	0 0	0	9	4	0
45 ACIN IRRIG WATER	0 0	0 0	3 00	3 00	6 00	0 0	0 0	0 0	3 00	0 0	3 00	0 0						

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0 0	0 0	0 0	0 0	0 0	203 50	0 0	0 0	0 0	0 0	0 0	0 0	203 50
TOTAL EXPENSES	ACRE	1 20	3 76	21 18	16 39	25 46	30 18	2 33	36 20	18 38	0 0	12 93	0 0	174 42
RETURNS TO LAND LABOR CAPITAL MACHINERY, OVERHEAD RISK AND MANAGEMENT														29 08
ANNUAL CAPITAL	DOL	5 92	6 73	8 50	9 86	12 02	0 0	0 19	3 21	4 74	4 74	5 82	5 82	67 57
LABOR REQUIREMENTS BY MONTH														
MACHINERY LABOR	HR	0 03	0 10	0 0	0 0	0 0	0 22	0 23	0 26	0 12	0 0	0 0	0 0	0 96
IRRIGATION LABOR	HR	0 0	0 0	0 16	0 16	0 32	0 0	0 0	0 0	0 16	0 0	0 16	0 0	0 97
TOTAL LABOR	HR	0 03	0 10	0 16	0 16	0 32	0 22	0 23	0 26	0 28	0 0	0 16	0 0	1 93
IRRIGATION WATER	INCH	0 0	0 0	3 00	3 00	6 00	0 0	0 0	0 0	3 00	0 0	3 00	0 0	18 00

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR	TAX	TOTAL FIXED	REPAIR	FUEL	LUB	TOTAL VARIABLE	INT	HR/TIME
TRACTOR(2)	2	2 88	0 16	0 41	3 44	1 62	4 03	0 60	6 25	3 70	1 00
TRACTOR(4)	4	4 50	0 25	0 64	5 38	2 53	6 30	0 94	9 77	5 79	1 00
PICKUP	9	1 55	0 06	0 17	1 88	0 42	4 67	0 70	5 79	1 46	1 00
OFFSET DISK	37	5 93	0 25	0 72	6 90	1 34	0 0	0 0	1 34	5 93	0 13
SWEEP	41	4 53	0 19	0 55	5 27	1 58	0 0	0 0	1 58	4 53	0 19
DRILL WO/FERT	57	3 29	0 14	0 40	3 83	0 75	0 0	0 0	0 75	3 30	0 20
DRILL WO/FERT	57	3 29	0 14	0 40	3 83	0 75	0 0	0 0	0 75	3 30	0 20
SPRAYER	68	3 25	0 12	0 34	3 71	1 31	0 0	0 0	1 31	2 88	0 06
DRY FERT SPREAD	71	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 04

OPERATION	ITEM NO	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL OIL LUB REPAIR PER ACRE	FIXED COSTS PER ACRE
SWEEP	4 41	JUL	1 00	0 229	0 189	2 33	4 18
OFFSET DISK	4 37	AUG	1 00	0 157	0 129	1 57	3 25
DRY FERT SPREAD	2 71	AUG	1 00	0 047	0 039	0 27	0 30
PICKUP	9	AUG	0 05	0 060	0 055	0 32	0 18
DRILL WO/FERT	4 57	SEP	0 50	0 119	0 098	1 13	1 90
DRILL WO/FERT	57	SEP	0 50	0 0	0 098	0 07	0 70
SPRAYER	4 68	JAN	0 50	0 035	0 029	0 35	0 54
SPRAYER	4 68	FEB	0 50	0 035	0 029	0 35	0 54
PICKUP	9	FEB	0 05	0 060	0 055	0 32	0 18
OFFSET DISK	4 37	JUN	1 00	0 157	0 129	1 57	3 25
PICKUP	9	JUN	0 05	0 060	0 055	0 32	0 18
TOTAL				0 957	0 905	8 57	15 22

COLUMN NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFIC-ENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	13 PURCHASE PRICE	14 FUEL TYPE	15 HOURS OF LIFE	16 HP
TRACTOR(2)	2	80 0	24500	4 5	0 88	1 20	0 000631	1 60	500	10 0	0 680	0 920	24500	3	12000	80
TRACTOR(4)	4	125 0	38300	4 5	0 88	1 20	0 000631	1 50	600	10 0	0 680	0 920	38300	3	2000	25
PICKUP	9	0 8	8500	20 0	0 88	0 60	0 000631	1 60	500	8 0	0 600	0 885	8500	1	8000	140
OFFSET DISK	37	16 0	7200	4 8	0 83	0 65	0 000251	1 80	100	10 0	0 600	0 885	7200	0	2000	0
SWEEP	41	14 0	5500	4 1	0 76	1 00	0 000251	1 80	100	0 0	0 600	0 885	5500	0	2000	0
DRILL WO/FERT	57	13 0	4000	4 5	0 72	0 65	0 000251	1 80	100	10 0	0 600	0 885	4000	0	2000	0
SPRAYER	68	36 0	4200	5 0	0 80	0 65	0 000251	1 80	125	8 0	0 600	0 885	4200	0	500	0
DRY FERT SPREAD	71	60 0	0	5 3	0 67	0 75	0 000251	1 80	50	10 0	0 560	0 885	0	0	1000	0

CIRCULAR SPRINKLER SYSTEM HININGER MACHINERY COMPLEMENT 11
WELL DEPTH-480 DEPTH TO WATER LEVEL-360 GALLONS PER MINUTE-850 EQUIPMENT COMPLEMENT 11
LIGHT INDUSTRIAL ENGINE-225 HP NATURAL GAS 05/31/83 1000000000 PRICE VECTOR 1

NO NAME CHANGES HAVE BEEN STORED WITH THIS BUDGET

	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE	RW CL	VALUE
PARAMETER CHGS-->	18	0 053846										
IRRIGATION------>		4 000	2 070	2 360	0 100	0 060	4 590	1 240	2 670	0 400	4 [illegible]	

ALFALFA HAY, DRYLAND 81602004
LOAM SOIL 01/02/84
OWN EQUIPMENT SOUTHWEST

OPERATING INPUTS:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
EST. COST	ACRE	90.000	0.200	18.00	________
PHOSPH (P2O5)	LBS.	0.320	60.000	19.20	________
INSECTICIDE	ACRE	10.000	1.000	10.00	________
MISCL EXPENSE	BL.	0.070	90.000	6.30	________
ANNUAL OPERATING CAPITAL	DOL.	0.150	11.986	1.80	________
LABOR CHARGES	HR.	4.250	4.005	17.02	________
MACHINERY FUEL, LUBE, REPAIRS	ACRE			45.86	________
TOTAL OPERATING COST				118.18	________

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 15.0%	DOL.	37.988	________
DEPR., TAXES, INSUR.	DOL.	43.852	________
LAND			
INTEREST AT 0.0%	DOL.	0.000	________
TAXES	DOL.	0.000	________
TOTAL FIXED COSTS		81.84	________

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
ALFALFA HAY	TONS	70.000	3.000	210.00	________
RETURNS ABOVE TOTAL OPERATING COSTS				91.82	________
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD, RISK AND MANAGEMENT				9.98	________

OWN MACHINERY PROVENCE

01/06/84 0000010000

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PROGRAM DEVELOPED BY DEPT. OF AGRI. ECON. OKLAHOMA STATE UNIVERSITY

RETURNS ABOVE TOTAL OPERATING COSTS
WHEN THE QUANTITY OF ALFALFA HAY RANGES FROM 2.50 TO 3.50
AND THE PRICE OF ALFALFA HAY RANGES FROM 60.00 TO 80.00

QUANTITY OF ALFALFA HAY

PRICE OF ALFALFA HAY	2.50	2.75	3.00	3.25	3.50
60.00	31.82	46.82	61.82	76.82	91.82
65.00	44.32	60.57	76.82	93.07	109.32
70.00	56.82	74.32	91.82	109 32	126.82
75.00	69.32	88.07	106.82	125.57	144.32
80.00	81.82	101.82	121.82	141.82	161.82

RETURNS NOT ADJUSTED FOR EFFECT OF YIELD CHANGES ON COSTS

BUDGET IDENTIFICATION NUMBER 816020040 606 6 ANNUAL CAPITAL MONTH 5 BUDGET RECORD NUMBER 256
BUDGET FILE 1

ALFALFA HAY, DRYLAND
LOAM SOIL
OWN EQUIPMENT

81602004
01/02/84
SOUTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SEP	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 ALFALFA HAY	0.00	0.00	0.00	0.00	1.20	1 00	0.00	0.00	0.00	0 80	0.00	0.00	-1 000	0 000	3.	81	2.	0.
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 EST. COST	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90.000	0.000	7.	419.	3.	0
13 PHOSPH (P205)	0.00	60.00	0.00	0.00	0.00	0.00	0.00	0.00	0 00	0.00	0.00	0.00	-1 000	0 000	12	214.	3.	0.
14 INSECTICIDE	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10 000	0.000	7	240	3	0
15 MISCL EXPENSE	0.00	0.00	0.00	0.00	36.00	30.00	0.00	0.00	0.00	24.00	0.00	0.00	0.070	0.000	6.	400	3.	0.
MACHINERY REQUIREMENTS						TIMES OVER							XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
38 ROLLOVER MB PLOW	0 00	0 00	0.00	0.00	0.00	0.20	0.00	0.00	0 00	0.00	0 00	0 00	0.000	0.000	3	36.	4	0.
39 OFFSET DISK	0 00	0.00	0 00	0.00	0 00	0.00	0 20	0 00	0 20	0.00	0 00	0 00	0.000	0 000	3.	41	4	0.
40 SPRINGTOOTH	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0.00	0.40	0 00	0 00	0 00	0 000	0 000	3	46.	4	0
42 DRILL	0 00	0 00	0.00	0 00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0 00	0.000	0.000	3.	50.	4	0.
43 S P SWATHER	0.00	0.00	0.00	0.00	1 00	1 00	0.00	0.00	0 00	1 00	0.00	0.00	0.000	0 000	0.	14	4	0.
44 HAY BALER	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0 00	0 00	1.00	0.00	0.00	0 000	0.000	3.	88	4	0
45 TRACTOR(3)	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0 00	0.00	0.00	0.00	0.000	0 000	0.	3	4	0.
50 OTHER LABOR	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10	0.10	0.00	0.00						

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0 00	0 00	0.00	0.00	84 00	70 00	0 00	0 00	0 00	56 00	0 00	0 00	210 00
TOTAL EXPENSES	ACRE	18.00	19 78	0 00	10 00	16.75	17 07	0 32	0.00	1 53	15 91	0 00	0 00	99 36
RETURNS TO LAND, LABOR, CAPITAL, MACHINERY, OVERHEAD, RISK, AND MANAGEMENT														110 64
ANNUAL CAPITAL	DOL.	1 50	3.15	3.15	3.98	0.00	0.00	0.03	0.03	0.15	0 00	0.00	0.00	11.99
		LABOR REQUIREMENTS BY MONTH												
MACHINERY LABOR	HR	0.00	0.06	0.00	0.00	1.14	1 21	0.03	0.00	0.12	1 14	0 00	0 00	3.71
OTHER LABOR	HR.	0.00	0.00	0.00	0 00	0.10	0 00	0.00	0.00	0.10	0.10	0 00	0 00	0.30
TOTAL LABOR	HR.	0.00	0.06	0.00	0.00	1 24	1 21	0.03	0 00	0 22	1 24	0.00	0.00	4 01

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR	TAX	TOTAL FIXED	REPAIR	FUEL	LUB.	TOTAL VARIABLE	INT	HR/TIME
TRACTOR(3)	3	4 58	0 25	0.65	5 48	2 68	6 30	1 03	10 62	6 31	1 00
S.P SWATHER	14	37 15	1 15	2.85	41.15	13.65	3.79	0.57	18 02	28 82	0.12
ROLLOVER MB PLOW	36	18 18	0.83	2.30	21.32	2.07	0.00	0.00	2.07	20 86	0 27
OFFSET DISK	41	10.29	0.44	1.25	11 98	2.15	0.00	0.00	2.15	11 03	0.12
SPRINGTOOTH	46	4.12	0.18	0.50	4.79	0.93	0.00	0.00	0.93	4.41	0.09
DRILL	50	7.16	0.31	0.87	8.34	5.65	0.00	0 00	5.65	7 68	0.22
HAY BALER	88	3.71	0.10	0.27	4.08	2.93	0.00	0.00	2.93	2.61	0 82

OPERATION	ITEM NO.	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL, OIL, LUB., REPAIR PER ACRE	FIXED COSTS PER ACRE
ROLLOVER MB PLOW	3.36	JUN	0.20	0.066	0.054	0.75	3.00
S.P SWATHER	14	JUN	1.00	0.149	0.124	2.23	8 68
HAY BALER	3.88	JUN	1.00	0.993	0.821	11.99	16 15
OFFSET DISK	3.41	JUL	0.20	0 028	0.023	0 32	0 83
OFFSET DISK	3.41	SEP	0 20	0.028	0 023	0 32	0 83
SPRINGTOOTH	3.46	SEP	0 40	0 045	0 037	0.47	0.82
DRILL	3.50	SEP	0.20	0.052	0 043	0.75	1 25
S P SWATHER	14	OCT	1.00	0.149	0.124	2.23	8.68
HAY BALER	3.88	OCT	1 00	0.993	0.821	11 99	16 15
TRACTOR(3)	3	FEB	0.05	0.060	0.055	0.58	0 65
S.P SWATHER	14	MAY	1 00	0 149	0.124	2.23	8.68
HAY BALER	3.88	MAY	1 00	0 993	0 821	11 99	16 15
TOTAL				3.705	3.070	45.86	81 84

COLUMN / NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFIC-ENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	13 PURCHASE PRICE	14 FUEL TYPE	15 HOURS OF LIFE	16 HP
TRACTOR(3)	3	125.0	39000	4 5	0 88	1 25	0 000631	1 60	600	10 0	0 680	0 920	39000.	3	12000	125
S.P SWATHER	14	16 0	28500.	5 4	0.77	1 00	0 002510	1 30	100	5 0	0 660	0 880	28500	3	1500	75
ROLLOVER MB PLOW	36	7 5	11500	4 5	0 90	1 50	0.002510	1 30	50	10 0	0 635	0 895	11500	0	5000	0
OFFSET DISK	41	18 0	12500	4 8	0 83	0 60	0 000251	1 80	100.	10 0	0 600	0 885	12500	0	2000	0
SPRINGTOOTH	46	24 0	5000	5 3	0.70	0 55	0 000251	1 80	100	10 0	0 600	0 885	5000	0	2000	0
DRILL	50	13 3	8700	4 0	0.72	0 65	0 000251	1 80	100	10 0	0 600	0 885	8700	0	1000	0
HAY BALER	88.	5.0	8000	3 0	0.67	0 80	0.002510	1 30	300	5 0	0 560	0 885	8000	0	2000	0

OWN MACHINERY PROVENCE MACHINERY COMPLEMENT 6
EQUIPMENT COMPLEMENT 6
01/06/84 0000010000 PRICE VECTOR 6

LINE CHANGE LINE CHANGE LINE CHANGE LINE CHANGE LINE CHANGE
GENERAL NAME CHANGE->419 EST COST

NO COMPLEMENT CHANGES HAVE BEEN STORED WITH THIS BUDGET

GRAIN SORGHUM, DRYLAND, SANDY SOIL, CUSTOM HARVEST — 73104108 — 01/02/84 — NORTHWEST

OPERATING INPUTS:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
GRAIN SORG SEED	LBS.	0.750	3.000	2.25	
NITROGEN (N)	LBS	0.330	35.000	11.55	
INSECTICIDE	ACRE	6.500	1.000	6.50	
CUSTOM COMBINE	ACRE	12.000	1.000	12.00	
CUSTOM HAULING	BU.	0.200	21.000	4.20	
ANNUAL OPERATING CAPITAL	DOL.	0.150	9.454	1.42	
LABOR CHARGES	HR.	4.250	0.664	2 82	
MACHINERY FUEL, LUBE, REPAIRS	ACRE			6.20	
TOTAL OPERATING COST				46.94	

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 15.0%	DOL.	6.474	
DEPR., TAXES, INSUR.	DOL.	6.357	
LAND			
INTEREST AT 0.0%	DOL.	0.000	
TAXES	DOL.	0.000	
TOTAL FIXED COSTS		12.83	

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
GRAIN SORGHUM	CWT.	4 600	21 000	96 60	
PASTURE	AUMS	0.000	0.750	0.00	
TOTAL RECEIPTS				96.60	
RETURNS ABOVE TOTAL OPERATING COSTS				49 66	
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD, RISK AND MANAGEMENT				36.82	

DRYLAND - NORTHWEST OKLA. & OKLA. PANHANDLE SANDY SOILS — GRIFFITH

12/09/83 1000000000

PROCESSED BY DEPT OF AGRI ECON. - OKLAHOMA STATE UNIVERSITY
PROGRAM DEVELOPED BY DEPT. OF AGRI. ECON. OKLAHOMA STATE UNIVERSITY

RETURNS ABOVE TOTAL OPERATING COSTS
WHEN THE QUANTITY OF GRAIN SORGHUM RANGES FROM 17 00 TO 25 00
AND THE PRICE OF GRAIN SORGHUM RANGES FROM 4.10 TO 5 10

QUANTITY OF GRAIN SORGHUM

PRICE OF GRAIN SORGHUM	17.00	19.00	21.00	23 00	25.00
4 10	22 76	30.96	39 16	47 36	55.56
4.35	27 01	35 71	44 41	53 11	61 81
4.60	31 26	40.46	49 66	58 86	68 06
4 85	35.51	45.21	54 91	64 61	74 31
5 10	39 76	49.96	60 16	70 36	80 56

RETURNS NOT ADJUSTED FOR EFFECT OF YIELD CHANGES ON COSTS

BUDGET IDENTIFICATION NUMBER 73104108011O111 ANNUAL CAPITAL MONTH 10 BUDGET RECORD NUMBER 129
BUDGET FILE 1

GRAIN SORGHUM
DRYLAND SANDY SOIL
CUSTOM HARVEST

73104108
01/02/84
NORTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SEP	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 GRAIN SORGHUM	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	21 00	0 00	0 00	-1 000	0 000	16	73	2	0
2 PASTURE	0 00	0.00	0.00	0.00	0 00	0 00	0 00	0.00	0 00	0 25	0 50	0 00	0 000	0 000	10	150	2	0.
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 GRAIN SORG SEED	0 00	0 00	0 00	0 00	0 00	3 00	0 00	0.00	0 00	0 00	0.00	0 00	-1 000	0 000	12	173	3	0
12 NITROGEN (N)	0 00	0 00	0 00	0 00	35 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-1 000	0 000	12	211	3	0
13 INSECTICIDE	0 00	0 00	0 00	0 00	0 00	0 00	1 00	0 00	0 00	0 00	0 00	0 00	6 500	0 000	7	240	3	0
15 CUSTOM COMBINE	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	1 00	0 00	0 00	12 000	0 000	7	305	3	0
16 CUSTOM HAULING	0.00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	21 00	0 00	0 00	0.200	0 000	2.	306.	3	0
MACHINERY REQUIREMENTS						TIMES OVER							XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
38 OFFSET DISK	0 00	0 00	1 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 000	0 000	3.	38	4	0
42 PLANTER	0 00	0 00	0 00	0 00	0 00	1 20	0 00	0 00	0 00	0 00	0 00	0 00	0 000	0 000	3.	62	4	0
43 FIELD CULTIVATOR	0 00	0 00	0 00	0 00	0.00	1 00	1 00	0 00	0.00	0 00	0 00	0 00	0 000	0 000	3	48	4	0

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0 00	0.00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	96 60	0.00	0 00	96 60
TOTAL EXPENSES	ACRE	0 00	0 00	1 30	0 00	11 55	5 64	8 01	0 00	0 00	16 20	0 00	0 00	42 70
RETURNS TO LAND, LABOR, CAPITAL, MACHINERY OVERHEAD, RISK, AND MANAGEMENT														53 90
ANNUAL CAPITAL	DOL	0 00	0 00	0 11	0 11	1 07	1 54	2 21	2 21	2 21	0 00	0 00	0 00	9 45

LABOR REQUIREMENTS BY MONTH

MACHINERY LABOR	HR	0 00	0 00	0 14	0.00	0 00	0 35	0 17	0.00	0 00	0 00	0.00	0 00	0 66

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR.	TAX	TOTAL FIXED	REPAIR	FUEL	LUB	TOTAL VARIABLE	INT	HR/TIME
TRACTOR(3)	3	3 72	0 20	0 53	4 45	2 09	5 52	0 83	8 44	5 12	1 00
OFFSET DISK	38	4 28	0 18	0 52	4 98	2 01	0 00	0 00	2 01	4 59	0 12
PLANTER	62	10 70	0.46	1 30	12 46	3 43	0 00	0 00	3 43	11 47	0 12
FIELD CULTIVATOR	48	3 79	0 16	0 46	4 41	1 32	0 00	0 00	1 32	4 06	0 14

OPERATION	ITEM NO	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL,OIL LUB, REPAIR PER ACRE	FIXED COSTS PER ACRE
OFFSET DISK	3,38	MAR	1 00	0.139	0 115	1 30	2 31
PLANTER	3,62	JUN	1 20	0 179	0.148	1.88	5 09
FIELD CULTIVATOR	3,48	JUN	1 00	0 173	0 143	1 51	2 71
FIELD CULTIVATOR	3,48	JUL	1.00	0.173	0 143	1 51	2.71
TOTAL				0 664	0.548	6 20	12.83

COLUMN NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFIC-ENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	13 PURCHASE PRICE	14 FUEL TYPE	15 HOURS OF LIFE	16 HP
TRACTOR(3)	3	100 0	31640	4 5	0.88	1 20	0 000631	1 60	600	10 0	0 680	0 920	31640	3	12000	100
OFFSET DISK	38	18 0	7800	4 8	0 83	0 85	0 000251	1 80	150	10 0	0 600	0 885	7800	0	2000	0
FIELD CULTIVATOR	48	20 0	4600	3 8	0 76	1 00	0.000251	1 80	100	10 0	0 600	0 885	4600	0	2000	0
PLANTER	62	20 0	7800	5 0	0.67	0.80	0 000631	1 60	60	10 0	0 600	0 885	7800	0	1200	0

DRYLAND - NORTHWEST OKLA & OKLA PANHANDLE GRIFFITH MACHINERY COMPLEMENT 11
SANDY SOILS EQUIPMENT COMPLEMENT 11
12/08/83 1000000000 PRICE VECTOR 1

NO NAME CHANGES HAVE BEEN STORED WITH THIS BUDGET

NO COMPLEMENT CHANGES HAVE BEEN STORED WITH THIS BUDGET

BERMUDA PASTURE, DRYLAND
100# NITROGEN

83608301
01/02/84
SOUTHWEST

OPERATING INPUTS:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
BERMUDA EST.	ACRE	180.000	0 100	18.00	________
NITROGEN (N)	LBS.	0 290	100.000	29.00	________
PHOSPH (P2O5)	LBS.	0.320	20 000	6.40	________
ANNUAL OPERATING CAPITAL	DOL.	0.150	18.570	2.79	________
LABOR CHARGES	HR.	4.250	0.121	0.51	________
MACHINERY FUEL,LUBE,REPAIRS	ACRE			1.17	________
TOTAL OPERATING COST				57.87	________

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 15.0%	DOL.	0.695	________
DEPR.,TAXES,INSUR.	DOL.	0.603	________
LAND			
INTEREST AT 0 0%	DOL.	0.000	________
TAXES	DOL	0.000	________
TOTAL FIXED COSTS		1 30	________

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PASTURE	AUMS	0 000	4.500	0.00	________
RETURNS ABOVE TOTAL OPERATING COSTS				-57.87	________
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD,RISK AND MANAGEMENT				-59.17	________

$60 PER ACRE ESTABLISHMENT
PRO-RATED OVER 10 YR PERIOD

PROVENCE

12/08/83 0000010000

PROCESSED BY DEPT. OF AGRI. ECON. - OKLAHOMA STATE UNIVERSITY
PROGRAM DEVELOPED BY DEPT. OF AGRI ECON. OKLAHOMA STATE UNIVERSITY

BUDGET IDENTIFICATION NUMBER 836083010 606 6 ANNUAL CAPITAL MONTH 5 BUDGET RECORD NUMBER 289
BUDGET FILE 1

BERMUDA PASTURE, DRYLAND
1COØ NITROGEN

8360830'
0'/C2/84
SOUTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SE	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 PASTURE	0.00	0.00	0.00	0.00	0 50	0 80	0.80	0 60	0 80	0 70	0 30	0.00	0.000	0 000	10	150	2	0.
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 BERMUDA EST	0 10	0 00	0.00	0 00	0.00	0.00	0 00	0 00	0 00	0.00	0.00	0 00	180 000	0 000	7	190	3	0.
12 NITROGEN (N)	0 00	0.00	0 00	0 00	50 00	0 00	50 00	0 00	0 00	0 00	0.00	0 00	-1 000	0 000	12.	211	3.	0.
13 PHOSPH (P2O5)	0 00	0.00	0.00	0 00	20 00	0.00	0 00	0 30	0.00	0 00	0.00	0.00	-1 000	0.000	12.	214.	3.	0
MACHINERY REQUIREMENTS					TIMES OVER								XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
38 TRACTOR(3)	0.00	0 00	0.00	0.00	0.05	0 00	0.05	0 00	0.00	0 00	0 00	0.00	0 000	0 000	0	3	4.	0

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
TOTAL EXPENSES	ACRE	18 00	0 00	0 00	0 00	21 48	0 00	15 08	0 00	0 00	0 00	0 00	0.00	54 57
RETURNS TO LAND, LABOR, CAPITAL, MACHINERY, OVERHEAD, RISK, AND MANAGEMENT														-54 57
ANNUAL CAPITAL	DOL	2.76	2.76	2.76	2.76	0.00	0.00	1 26	1 26	1 26	1 26	1 26	1 26	18 57

LABOR REQUIREMENTS BY MONTH

MACHINERY LABOR	HR	0 00	0 00	0.00	0 00	0 06	0.00	0 06	0 00	0 00	0 00	0.00	0.00	0 12

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR	TAX	TOTAL FIXED	REPAIR	FUEL	LUB	TOTAL VARIABLE	INT	HR/TIME
TRACTOR(3)	3	4 58	0 25	0 65	5 48	2 68	6 90	1 03	10 62	6 3'	1 00

OPERATION	ITEM NO	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL OIL,LUB , REPAIR PER ACRE	FIXED COSTS PER ACRE
TRACTOR(3)	3	JUL	0 05	0 060	0 055	0 58	0 65
TRACTOR(3)	3	MAY	0.05	0 060	0 055	0 58	0 65
TOTAL				0 120	0 110	1 17	1 30

COLUMN NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFIC-ENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	13 PURCHASE PRICE	14 FUEL TYPE	15 HOURS OF LIFE	16 HP
TRACTOR(3)	3	125 0	39000.	4 5	0 88	1.25	0 000631	1 60	600	10.0	0 680	0 920	39000	3	12000.	125

$60 PER ACRE ESTABLISHMENT
PRO-RATED OVER 10 YR PERIOD

12/08/83 PROVENCE 0000010000

MACHINERY COMPLEMENT 6
EQUIPMENT COMPLEMENT 6
PRICE VECTOR 6

LINE CHANGE LINE CHANGE LINE CHANGE LINE CHANGE LINE CHANGE
GENERAL NAME CHANGE->190 BERMUDA EST.

DRYLAND WHEAT — 7614350C
HARPER, WOODWARD & ELLIS — 08/01/83
CUSTOM HARVEST — NORTHWEST

OPERATING INPUTS:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
WHEAT SEED	BU.	4.250	0.750	3.19	________
RNTFERTSPRD/ACRE	ACRE	1 000	1 000	1 00	________
CROP INSURANCE	DOL.	0.140	10.500	1 47	________
CUSTOM COMBINE	ACRE	12.000	1.000	12.00	________
CUSTOM COMBINE	BU.	0.120	2.000	0.24	________
CUSTOM HAULING	BU.	0.220	23.000	5.06	________
NITROGEN (N)	LBS.	0.330	30.000	9.90	________
PHOSPH (P205)	LBS.	0.290	30 000	8 70	________
2-4-D	ACRE	1.700	1.000	1.70	________
ANNUAL OPERATING CAPITAL	DOL	0 140	23 153	3.24	________
LABOR CHARGES	HR.	4.250	0 785	3.33	________
MACHINERY FUEL, LUBE, REPAIRS	ACRE			6.20	________
TOTAL OPERATING COST				56.03	________

FIXED COSTS		VALUE	YOUR VALUE
MACHINERY			
INTEREST AT 14.0%	DOL.	6.372	________
DEPR., TAXES, INSUR.	DOL.	6.739	________
LAND			
INTEREST AT 0 0%	DOL	0.0	________
TAXES	DOL.	0.0	________
TOTAL FIXED COSTS		13.11	________

PRODUCTION:	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
WHEAT	BU.	3.700	22 000	81 40	________
S.G. PASTURE	AUMS	0.0	0 500	0.0	________
TOTAL RECEIPTS				81 40	________
RETURNS ABOVE TOTAL OPERATING COSTS				25.37	________
RETURNS ABOVE ALL COSTS EXCEPT OVERHEAD, RISK AND MANAGEMENT				12.26	________

FERTILIZER 100#: 30-30-0 — HININGER

05/31/83 — 1000000000

PROCESSED BY DEPT OF AGRI ECON. - OKLAHOMA STATE UNIVERSITY
PROGRAM DEVELOPED BY DEPT OF AGRI ECON. OKLAHOMA STATE UNIVERSITY

RETURNS ABOVE TOTAL OPERATING COSTS
WHEN THE QUANTITY OF WHEAT RANGES FROM 16 00 TO 28 00
AND THE PRICE OF WHEAT RANGES FROM 3.20 TO 4.20

	QUANTITY OF WHEAT				
PRICE OF WHEAT	16.00	19 00	22 00	25 00	28.00
3.20	-4.83	4 77	14.37	23.97	33 57
3 45	-0.83	9.52	19 87	30.22	40.57
3.70	3 17	14.27	25 37	36 47	47 57
3.95	7.17	19 02	-30 87	42 72	54 57
4.20	11 17	23 77	36.37	48 97	61 57

RETURNS NOT ADJUSTED FOR EFFECT OF YIELD CHANGES ON COSTS

BUDGET IDENTIFICATION NUMBER 76143500011011 ANNUAL CAPITAL MONTH 6 BUDGET RECORD NUMBER 147
BUDGET FILE 1

DRYLAND WHEAT 76143500
HARPER WOODWARD & ELLIS 08/01/83
CUSTOM HARVEST NORTHWEST

LINE	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUN	7 JUL	8 AUG	9 SEP	10 OCT	11 NOV	12 DEC	13 PRICE	14 WEIGHT	15 UNIT CODE	16 ITEM CODE	17 TYPE	18 CONT
PRODUCTION					NUMBER OF UNITS													
1 WHEAT	0.0	0.0	0.0	0.0	0.0	22.00	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	0.0	2	76	2	0
2 S G PASTURE	0.05	0.05	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	0.15	-1.000	0.0	10	153	2	0
OPERATING INPUTS					RATE/UNIT								PRICE	NUMBER UNITS	UNIT CODE	ITEM CODE	TYPE	CONT
11 WHEAT SEED	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.75	0.0	0.0	0.0	-1.000	0.0	2	176	3	0
14 RNTFERTSPRD/ACRE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.0	0.0	0.0	0.0	-1.000	1.000	7	362	3	0
15 CROP INSURANCE	0.0	0.0	0.0	14.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.140	0.750	15	452	3	0
16 CUSTOM COMBINE	0.0	0.0	0.0	0.0	0.0	1.00	0.0	0.0	0.0	0.0	0.0	0.0	12.000	0.0	7	305	3	0
17 CUSTOM COMBINE	0.0	0.0	0.0	0.0	0.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.120	0.0	2	305	3	0
18 CUSTOM HAULING	0.0	0.0	1.00	0.0	0.0	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.220	0.0	2	306	3	0
19 NITROGEN (N)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.00	0.0	0.0	0.0	0.0	-1.000	0.0	12	211	3	0
20 PHOSPH (P2O5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.00	0.0	0.0	0.0	0.0	-1.000	0.0	12	214	3	0
21 2-4-D	0.50	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.700	1.000	7	251	3	0
MACHINERY REQUIREMENTS						TIMES OVER							XXXXX	XXXXX	POWER UNIT	MACH CODE	TYPE	CONT
38 SWEEP	0.0	0.0	0.0	0.0	0.0	1.00	0.0	1.00	0.0	0.0	0.0	0.0	0.0	0.0	4	43	4	0
39 ROD WEEDER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.0	0.0	0.0	0.0	0.0	4	55	4	0
40 HOE DRILL WO/FRT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.50	0.0	0.0	0.0	0.0	0.0	4	59	4	0
41 HOE DRILL WO/FRT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.50	0.0	0.0	0.0	0.0	0.0	0	59	4	0
42 SPRAYER	0.50	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4	68	4	0
43 DRY FERT SPREAD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.0	0.0	0.0	0.0	0.0	0.0	2	71	4	0
44 PICKUP	0.0	0.05	0.0	0.0	0.0	0.05	0.0	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0	9	4	0

MONTHLY SUMMARY OF RECEIPTS AND EXPENSES

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	ACRE	0.0	0.0	0.0	0.0	0.0	81.40	0.0	0.0	0.0	0.0	0.0	0.0	81.40
TOTAL EXPENSES	ACRE	.20	1.22	0.22	1.47	0.0	18.45	0.0	21.24	5.66	0.0	0.0	0.0	49.46
RETURNS TO LAND LABOR CAPITAL MACHINERY OVERHEAD RISK, AND MANAGEMENT														31.94
ANNUAL CAPITAL	DOL	2.34	2.44	2.46	2.58	2.58	0.0	0.0	1.77	2.24	2.24	2.24	2.24	23.15

LABOR REQUIREMENTS BY MONTH

MACHINERY LABOR	HR	0.03	0.10	0.0	0.0	0.0	0.18	0.0	0.23	0.24	0.0	0.0	0.0	0.78

MACHINERY FIXED AND VARIABLE COSTS PER HOUR

MACHINE	CODE	DEPR	INSUR	TAX	TOTAL FIXED	REPAIR	FUEL	LUB	TOTAL VARIABLE	INT	HR TIME
TRACTOR(2)	2	3.24	0.18	0.46	3.88	1.82	4.03	0.60	6.45	4.18	1.00
TRACTOR(4)	4	4.50	0.25	0.64	5.38	2.53	6.30	0.94	9.77	5.79	1.00
PICKUP	9	1.65	0.06	0.17	1.88	0.42	0.03	0.01	0.46	1.46	1.00
SWEEP	43	7.41	0.32	0.90	8.63	2.58	0.0	0.0	2.58	7.41	0.10
ROD WEEDER	55	4.03	0.17	0.49	4.70	0.91	0.0	0.0	0.91	4.04	0.10
HOE DRILL WO/FRT	59	4.36	0.21	0.59	5.65	1.10	0.0	0.0	1.10	4.86	0.20
HOE DRILL WO/FRT	59	4.86	0.21	0.59	5.65	1.10	0.0	0.0	1.10	4.66	0.20
SPRAYER	68	3.25	0.12	0.34	3.71	1.31	0.0	0.0	1.31	2.88	0.06
DRY FERT SPREAD	71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04

OPERATION	ITEM NO	DATE	TIMES OVER	LABOR HOURS	MACHINE HOURS	FUEL OIL LUB REPAIR PER ACRE	FIXED COSTS PER ACRE
SWEEP	4 43	AUG	1.00	0.122	0.101	1.34	2.85
DRY FERT SPREAD	2,71	AUG	1.00	0.047	0.039	0.28	0.34
PICKUP	9	AUG	0.05	0.060	0.055	0.03	0.18
ROD WEEDER	4 55	SEP	1.00	0.125	0.104	1.21	2.18
HOE DRILL WO/FRT	4 59	SEP	0.50	0.119	0.098	1.16	2.23
HOE DRILL WO/FRT	59	SEP	0.50	0.0	0.098	0.11	1.03
SPRAYER	4 68	JAN	0.50	0.035	0.029	0.35	0.54
SPRAYER	4 68	FEB	0.50	0.035	0.029	0.35	0.54
PICKUP	9	FEB	0.05	0.060	0.055	0.03	0.18
SWEEP	4 43	JUN	1.00	0.122	0.101	1.34	2.85
PICKUP	9	JUN	0.05	0.060	0.055	0.03	0.18
TOTAL				0.783	0.761	6.20	13.11

COLUMN / NAME OF MACHINE	1 CODE	2 WIDTH (FEET)	3 INITIAL LIST PRICE	4 SPEED (MPH)	5 FIELD EFFIC-ENCY	6 RC1	7 RC2	8 RC3	9 HOURS USED ANNUALLY	10 YEARS OWNED	11 RFV1	12 RFV2	3 PURCHASE PRICE	4 FUEL TYPE	15 HOURS OF LIFE	6 HP
TRACTOR(2)	2	30.0	27630	4.5	0.88	1.20	0.000631	1.60	600	10.0	0.680	0.920	27630	3	12000	80
TRACTOR(4)	4	125.0	38300	4.5	0.88	1.20	0.000631	1.60	600	10.0	0.680	0.920	38300	3	14000	125
PICKUP	9	0.5	8500	20.0	0.88	0.60	0.000631	1.60	500	8.0	0.600	0.885	8500	1	8000	1
SWEEP	43	24.0	9000	4.5	0.76	1.00	0.000251	1.80	100	10.0	0.600	0.885	9000	0	2000	0
ROD WEEDER	55	20.0	4900	4.8	0.83	0.65	0.000251	1.80	100	10.0	0.600	0.885	4900	0	2000	0
HOE DRILL WO/FRT	59	13.0	5900	4.5	0.72	0.65	0.000251	1.80	100	10.0	0.600	0.885	5900	0	2000	0
SPRAYER	68	36.0	4200	5.0	0.80	0.65	0.000251	1.80	125	8.0	0.600	0.885	4200	0	1500	0
DRY FERT SPREAD	71	60.0	0	5.3	0.67	0.75	0.000251	1.80	50	10.0	0.560	0.885	0	0	1000	0

FERTILIZER 100# 30-30-0 HININGER MACHINERY COMPLEMENT 1
EQUIPMENT COMPLEMENT 11
05/31/83 1000000000 PRICE VECTOR 1

NO NAME CHANGES HAVE BEEN STORED WITH THIS BUDGET

	RW	CL	VALUE	RW	CL	VALUE	RW	CL	VALUE	RW	CL	VALUE	RW	CL	VALUE	RW	CL	VALUE
MACH COMP CHGS-->	2	9	600.000000	4	9	600.000000	9	9	500.000000	43	9	100.000000	55	9	100.000000	59	9	00.000000
	68	9	125.000000	71	9	50.000000	2	2	90.000000	2	3	27630.0000	2	13	27630.0000	9	2	0.500000
	9	16	1.000000															

APPENDIX C

ABBREVIATIONS OF VARIABLE NAMES

Activities

ALFPRD	Alfalfa production (tons)
BGPRD	Bermuda grass production (tons)
WHTPRD	Wheat production (bu.)
GSGPRD	Grain sorghum production (cwt.)
BORROW	Capital borrowing ($)
LBRBUY	Labor borrowing ($)
NBUY	Nitrogen fertilizer purchase (lbs.)
PBUY	Phosphorus fertilizer purchase (lbs.)
JAINFL	Effluent available for application or storage in January (ac-in)
FBINFL	Effluent available for application or storage in February (ac-in)
MRINFL	Effluent available for application or storage in March (ac-in)
APINFL	Effluent available for application or storage in April (ac-in)
MYINFL	Effluent available for application or storage in May (ac-in)
JNINFL	Effluent available for application or storage in June (ac-in)
JLINFL	Effluent available for application or storage in July (ac-in)
AUINFL	Effluent available for application or storage in August (ac-in)
SPINFL	Effluent available for application or storage in September (ac-in)

Activities

OCINFL	Effluent available for application or storage in October (ac-in)
NVINFL	Effluent available for application or storage in November (ac-in)
DCINFL	Effluent available for application or storage in December (ac-in)
JASTOR	January effluent storage (ac-in)
FBSTOR	February effluent storage (ac-in)
MRSTOR	March effluent storage (ac-in)
APSTOR	April effluent storage (ac-in)
MYSTOR	May effluent storage (ac-in)
JNSTOR	June effluent storage (ac-in)
JLSTOR	July effluent storage (ac-in)
AUSTOR	August effluent storage (ac-in)
SPSTOR	September effluent storage (ac-in)
OCSTOR	October effluent storage (ac-in)
NVSTOR	November effluent storage (ac-in)
DCSTOR	December effluent storage (ac-in)
JASWW	Stored effluent available for application or storage in January (ac-in)
FBSWW	Stored effluent available for application or storage in February (ac-in)
MRSWW	Stored effluent available for application or storage in March (ac-in)
APSWW	Stored effluent available for application or storage in April (ac-in)

Activities

MYSWW	Stored effluent available for application or storage in May (ac-in)
JNSWW	Stored effluent available for application or storage in June (ac-in)
JLSWW	Stored effluent available for application or storage in July (ac-in)
AUSWW	Stored effluent available for application or storage in August (ac-in)
SPSWW	Stored effluent available for application or storage in September (ac-in)
OCSWW	Stored effluent available for application or storage in October (ac-in)
NVSWW	Stored effluent available for application or storage in November (ac-in)
DCSWW	Stored effluent available for application or storage in December (ac-in)
ALFSEL	Alfalfa selling (tons)
BGSEL	Bermuda grass selling (tons)
WHTSEL	Wheat selling (bu.)
GSGSEL	Grain sorghum selling (cwt.)
CAPTA	Capital transfer activity ($)
NRTA	Net returns transfer activity ($)

Constraints

LANDA	Producer's land, Tract A (acres)
LANDB	Producer's land, Tract B (acres)

Constraints

LANDC	Producer's land, Tract C (acres)
LABOR	Producer's labor (hrs)
OPCAP	Operating capital ($)
NIT	Nitrogen (lbs.)
PHOS	Phosphorus (lbs.)
JAIR	Transfer of January effluent to crop or storage (ac-in)
FBIR	Transfer of February effluent to crop or storage (ac-in)
MRIR	Transfer of March effluent to crop or storage (ac-in)
APIR	Transfer of April effluent to crop or storage (ac-in)
MYIR	Transfer of May effluent to crop or storage (ac-in)
JNIR	Transfer of June effluent to crop or storage (ac-in)
JLIR	Transfer of July effluent to crop or storage (ac-in)
AUIR	Transfer of August effluent to crop or storage (ac-in)
SPIR	Transfer of September effluent to crop or storage (ac-in)
OCIR	Transfer of October effluent to crop or storage (ac-in)
NVIR	Transfer of November effluent to crop or storage (ac-in)
DCIR	Transfer of December effluent to crop or storage (ac-in)
JAQ	Quantity of new effluent in January (ac-in)
FBQ	Quantity of new effluent in February (ac-in)
MRQ	Quantity of new effluent in March (ac-in)
APQ	Quantity of new effluent in April (ac-in)
MYQ	Quantity of new effluent in May (ac-in)
JNQ	Quantity of new effluent in June (ac-in)
JLQ	Quantity of new effluent in July (ac-in)
AUQ	Quantity of new effluent in August (ac-in)

Constraints

SPQ	Quantity of new effluent in September (ac-in)
OCQ	Quantity of new effluent in October (ac-in)
NVQ	Quantity of new effluent in November (ac-in)
DCQ	Quantity of new effluent in December (ac-in)
JATR	January stored effluent transfer (ac-in)
FBTR	February stored effluent transfer (ac-in)
MRTR	March stored effluent transfer (ac-in)
APTR	April stored effluent transfer (ac-in)
MYTR	May stored effluent transfer (ac-in)
JNTR	June stored effluent transfer (ac-in)
JLTR	July stored effluent transfer (ac-in)
AUTR	August stored effluent transfer (ac-in)
SPTR	September stored effluent transfer (ac-in)
OCTR	October stored effluent transfer (ac-in)
NVTR	November stored effluent transfer (ac-in)
DCTR	December stored effluent transfer (ac-in)
ALFTR	Alfalfa production transfer (tons)
BGTR	Bermuda grass production transfer (tons)
WHTTR	Wheat production transfer (bu.)
GSGTR	Grain sorghum production transfer (cwt.)
NTRET	Net returns ($)

APPENDIX D

PICTURE OF FIRST TWO YEARS OF IRRIGATION MODEL

		ALFPRD1	BGPRD1	WHTPRD1	BORROW1	LBRBUY1	NBUY1	PBUY1	JAINFL1	FBINFL1	MRINFL1	APINFL1	MYINFL1	JNINFL1	JLINFL1	AUINFL1	SPINFL1	OCINFL1	NVINFL1	DCINFL1
OBJ	N	-C	-B	-B	-T	-A	-T	-T												
LANDA1	L	1																		
LANDB1	L		1																	
LANDC1	E			1																
LABOR1	L	B	A	A		-1														
OPCAP1	L	B	B	B	-1															
NIT1	L		B	B			-1		-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A
PHOS1	L	B	B	A				-1	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A
JAIR1	L								-1											
FBIR1	L									-1										
MRIR1	L			A							-1									
APIR1	L	A		A								-1								
MYIR1	L	A	A	A									-1							
JNIR1	L	A	A											-1						
JLIR1	L	A	A												-1					
AUIR1	L	A	A													-1				
SPIR1	L	A	A	A													-1			
OCIR1	L																	-1		
NVIR1	L			A															-1	
DCIR1	L																			-1
JAQ1	E								1											
FBQ1	E									1										
MRQ1	E										1									
APQ1	E											1								
MYQ1	E												1							
JNQ1	E													1						
JLQ1	E														1					
AUQ1	E															1				
SPQ1	E																1			
OCQ1	E																	1		
NVQ1	E																		1	
DCQ1	E																			1
JATR1	L																			
FBTR1	L																			
MRTR1	L																			
APTR1	L																			
MYTR1	L																			
JNTR1	L																			
JLTR1	L																			
AUTR1	L																			
SPTR1	L																			
OCTR1	L																			
NVTR1	L																			
DCTR1	L																			
ALFTR1	L	-A																		
BGTR1	L		-A																	

	JASTOR1	FBSTOR1	MRSTOR1	APSTOR1	MYSTOR1	JNSTOR1	JLSTOR1	AUSTOR1	SPSTOR1	OCSTOR1	NVSTOR1	DCSTOR1	FBSWW1	MRSWW1	APSWW1	MYSWW1	JNSWW1	JLSWW1	AUSWW1	SPSWW1	OCSWW1	NVSWW1	DCSWW1
JAIR1	1																						
FBIR1		1											-1										
MRIR1			1											-1									
APIR1				1											-1								
MYIR1					1											-1							
JNIR1						1											-1						
JLIR1							1											-1					
AUIR1								1											-1				
SPIR1									1											-1			
OCIR1										1											-1		
NVIR1											1											-1	
DCIR1												1											-1
JATR1	-1												1										
FBTR1		-1												1									
MRTR1			-1												1								
APTR1				-1												1							
MYTR1					-1												1						
JNTR1						-1												1					
JLTR1							-1												1				
AUTR1								-1												1			
SPTR1									-1												1		
OCTR1										-1												1	
NVTR1											-1												1
DCTR1												-1											

	ALFSEL1	BGSEL1	CAPTA1	NRTA1	ALFPRD2	BGPRD2	WHTPRD2	BORROW2	LBRBUY2	NBUY2	PBUY2	JAINFL2	FBINFL2
OBJ	B	B			-C	-B	-B	-T	-A	-T	-T		
OPCAP1			1										
ALFTR1	1												
BGTR1		1											

1, 1

2, 1

		ALFPRD1	BGPRD1	WHTPRD1	BORROW1	LBRBUY1	NBUY1	PBUY1	JAINFL1	FBINFL1	MRINFL1	APINFL1	MYINFL1	JNINFL1	JLINFL1	AUINFL1	SPINFL1	OCINFL1	NVINFL1	DCINFL1	JASTOR1	FBSTOR1	MRSTOR1	APSTOR1	MYSTOR1	JNSTOR1	JLSTOR1	AUSTOR1	SPSTOR1	OCSTOR1	NVSTOR1	DCSTOR1	FBSWW1	MRSWW1	APSWW1	MYSWW1	JNSWW1	JLSWW1	AUSWW1	SPSWW1	OCSWW1	NVSWW1	DCSWW1	ALFSEL1	BGSEL1	CAPTA1	NRTA1	ALFPRD2	BGPRD2	WHTPRD2	BORROW2	LBRBUY2	NBUY2	PBUY2	JAINFL2	FBINFL2
NTRET1	L	C	B	B	T	A	T	T																																		-B	-B		1									
LANDA2	L																																													1								
LANDB2	L																																														1							
LANDC2	L																																															1						
LABOR2	L																																													B	A	A		-1				
OPCAP2	L																																											-1	-U	B	B	B	-1					
NIT2	L																																														B	B			-1		-A	-A
PHOS2	L																																													B	B	A				-1	-A	-A
JAIR2	L																																																				-1	
FBIR2	L																																																					-1
MRIR2	L																																															A						
APIR2	L																																													A		A						
MYIR2	L																																													A	A	A						
JNIR2	L																																													A	A							
JLIR2	L																																													A	A							
AUIR2	L																																													A	A							
SPIR2	L																																													A	A	A						
OCIR2	L																																																					
NVIR2	L																																															A						
DCIR2	L																																																					
JAQ2	E																																																				1	
FBQ2	E																																																					1
MRQ2	E																																																					
APQ2	E																																																					
MYQ2	E																																																					
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JATR2	L																																																					
FBTR2	L																																																					
MRTR2	L																																																					
APTR2	L																																																					
MYTR2	L																																																					
JNTR2	L																																																					
JLTR2	L																																																					
AUTR2	L																																																					
SPTR2	L																																																					
OCTR2	L																																																					
NVTR2	L																																																					
DCTR2	L																																																					
ALFTR2	L																																													-A								
BGTR2	L																																														-A							

3, 1

ALFPRD1 BGPRD1 WHTPRD1 BORROW1 LBRBUY1 NBUY1 PBUY1 JAINFL1 FBINFL1 MRINFL1 APINFL1 MYINFL1 JNINFL1 JLINFL1 AUINFL1 SPINFL1 OCINFL1 NVINFL1 DCINFL1 JASTOR1 FBSTOR1 MRSTOR1 APSTOR1 MYSTOR1 JNSTOR1 JLSTOR1 AUSTOR1 SPSTOR1 OCSTOR1 NVSTOR1 DCSTOR1 FBSWW1 MRSWW1 APSWW1 MYSWW1 JNSWW1 JLSWW1 AUSWW1 SPSWW1 OCSWW1 NVSWW1 DCSWW1 ALFSEL1 BGSEL1 CAPTA1 NRTA1 ALFPRD2 BGPRD2 WHTPRD2 BORROW2 LBRBUY2 NBUY2 PBUY2 JAINFL2 FBINFL2

		ALFPRD2	BGPRD2	WHTPRD2	BORROW2	LBRBUY2	NBUY2	PBUY2
WHTTR2	L			-B				
NTRET2	L	C	B	B	T	A	T	T
LANDA3	L							
LANDB3	L							
LANDC3	L							
LABOR3	L							
OPCAP3	L							
NIT3	L							
PHOS3	L							
JAIR3	L							
FBIR3	L							
MRIR3	L							
APIR3	L							
MYIR3	L							
JNIR3	L							
JLIR3	L							
AUIR3	L							
SPIR3	L							
OCIR3	L							
NVIR3	L							
DCIR3	L							
JAQ3	E							
FBQ3	E							
MRQ3	E							
APQ3	E							
MYQ3	E							
JNQ3	E							
JLQ3	E							
AUQ3	E							
SPQ3	E							
OCQ3	E							
NVQ3	E							
DCQ3	E							
JATR3	L							
FBTR3	L							
MRTR3	L							
APTR3	L							
MYTR3	L							
JNTR3	L							
JLTR3	L							
AUTR3	L							
SPTR3	L							
OCTR3	L							
NVTR3	L							
DCTR3	L							
ALFTR3	L							

1, 2

		MRINFL2	APINFL2	MYINFL2	JNINFL2	JLINFL2	AUINFL2	SPINFL2	OCINFL2	NVINFL2	DCINFL2	JASTOR2	FBSTOR2	MRSTOR2	APSTOR2	MYSTOR2	JNSTOR2	JLSTOR2	AUSTOR2	SPSTOR2	OCSTOR2	NVSTOR2	DCSTOR2	JASWW2	FBSWW2	MRSWW2	APSWW2	MYSWW2	JNSWW2	JLSWW2	AUSWW2	SPSWW2	OCSWW2	NVSWW2	DCSWW2	ALFSEL2	BGSEL2	WHTSFL2	CAPTA2	NRTA2	ALFPRD3	BGPRD3	WHTPRD3	BORROW3	LBRBUY3	NBUY3	PBUY3	JAINFL3	FBINFL3	MRINFL3	APINFL3	MYINFL3	JNINFL3	JLINFL3	AUINFL3	SPINFL3
OBJ	N																																			B	B	A			-C	-B	-B	-T	-A	-T	-T									
LANDA1	L																																																							
LANDB1	L																																																							
LANDC1	E																																																							
LABOR1	L																																																							
OPCAP1	L																																																							
NIT1	L																																																							
PHOS1	L																																																							
JAIR1	L																																																							
FBIR1	L																																																							
MRIR1	L																																																							
APIR1	L																																																							
MYIR1	L																																																							
JNIR1	L																																																							
JLIR1	L																																																							
AUIR1	L																																																							
SPIR1	L																																																							
OCIR1	L																																																							
NVIR1	L																																																							
DCIR1	L																																																							
JAQ1	E																																																							
FBQ1	E																																																							
MRQ1	E																																																							
APQ1	E																																																							
MYQ1	E																																																							
JNQ1	E																																																							
JLQ1	E																																																							
AUQ1	E																																																							
SPQ1	E																																																							
OCQ1	E																																																							
NVQ1	E																																																							
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		MRINFL2	APINFL2	MYINFL2	JNINFL2	JLINFL2	AUINFL2	SPINFL2	OCINFL2	NVINFL2	DCINFL2	JASTOR2	FBSTOR2	MRSTOR2	APSTOR2	MYSTOR2	JNSTOR2	JLSTOR2	AUSTOR2	SPSTOR2	OCSTOR2	NVSTOR2	DCSTOR2	JASWW2	FBSWW2	MRSWW2	APSWW2	MYSWW2	JNSWW2	JLSWW2	AUSWW2	SPSWW2	OCSWW2	NVSWW2	DCSWW2	ALFSEL2	BGSEL2	WHTSEL2	CAPTA2	NRTA2	ALFPRD3	BGPRD3	WHTPRD3	BORROW3	LBRBUY3	NBUY3	PBUY3	JAINFL3	FBINFL3	MRINFL3	APINFL3	MYINFL3	JNINFL3	JLINFL3	AUINFL3	SPINFL3
NTRET1	L																																																						
LANDA2	L																																																						
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LANDC2	L																																																						
LABOR2	L																																																						
OPCAP2	L																																						1																	
NIT2	L	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A																																												
PHOS2	L	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A																																												
JAIR2	L										1												-1																															
FBIR2	L											1												-1																														
MRIR2	L	-1										1												-1																													
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JLIR2	L					-1										1												-1																									
AUIR2	L						-1										1												-1																								
SPIR2	L							-1										1												-1																							
OCIR2	L								-1										1												-1																						
NVIR2	L									-1										1												-1																					
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JLQ2	E					1																																																	
AUQ2	E						1																																																
SPQ2	E							1																																															
OCQ2	E								1																																														
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OCTR2	L																				-1												1																					
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DCTR2	L																						-1																																
ALFTR2	L																																			1																			
BGTR2	L																																				1																		

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		MRINFL2	APINFL2	MYINFL2	JNINFL2	JLINFL2	AUINFL2	SPINFL2	OCINFL2	NVINFL2	DCINFL2	JASTOR2	FBSTOR2	MRSTOR2	APSTOR2	MYSTOR2	JNSTOR2	JLSTOR2	AUSTOR2	SPSTOR2	OCSTOR2	NVSTOR2	DCSTOR2	JASWW2	FBSWW2	MRSWW2	APSWW2	MYSWW2	JNSWW2	JLSWW2	AUSWW2	SPSWW2	OCSWW2	NVSWW2	DCSWW2	ALFSEL2	BGSEL2	WHISEL2	CAPTA2	NRTA2	ALFPRD3	BGPRD3	WHTPRD3	BOROW3	LBRBUY3	NBUY3	PBUY3	JAINFL3	FBINFL3	MRINFL3	APINFL3	MYINFL3	JNINFL3	JLINFL3	AUINFL3	SPINFL3
WHTTR2	L																																					1																		
NTRET2	L																																			-B	-B	-A		1																
LANDA3	L																																								1															
LANDB3	L																																									1														
LANDC3	L																																										1													
LABOR3	L																																								B	A	A		-1											
OPCAP3	L																																						-1	-U	B	B	B	-1												
NIT3	L																																									B	B			-1		-A	-A	-A	-A	-A	-A	-A	-A	-A
PHOS3	L																																								B	B	A				-1	-A	-A	-A	-A	-A	-A	-A	-A	-A
JAIR3	L																																															-1								
FBIR3	L																																																-1							
MRIR3	L																																										A							-1						
APIR3	L																																								A		A								-1					
MYIR3	L																																								A	A	A									-1				
JNIR3	L																																								A	A											-1			
JLIR3	L																																								A	A												-1		
AUIR3	L																																								A	A													-1	
SPIR3	L																																								A	A	A												-1
OCIR3	L																																																							
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NVTR3	L																																																							
DCTR3	L																																																							
ALFTR3	L																																								-A															

		JLSTOR20	AUSTOR20	SPSTOR20	OCSTOR20	NVSTOR20	DCSTOR20	JASWW20	FBSWW20	MRSWW20	APSWW20	MYSWW20	JNSWW20	JLSWW20	AUSWW20	SPSWW20	OCSWW20	NVSWW20	DCSWW20	ALFSEL20	BGSEL20	WHTSEL20	CAPTA20	NRTA20	B
OBJ	N						X													B	B	A			
LANDA1	L																								B
LANDB1	L																								B
LANDC1	E																								B
LABOR1	L																								D
OPCAP1	L																								E
NIT1	L																								
PHOS1	L																								
JAIR1	L																								
FBIR1	L																								
MRIR1	L																								
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MYIR1	L																								
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JLIR1	L																								
AUIR1	L																								
SPIR1	L																								
OCIR1	L																								
NVIR1	L																								
DCIR1	L																								
JAQ1	E																								C
FBQ1	E																								C
MRQ1	E																								C
APQ1	E																								C
MYQ1	E																								C
JNQ1	E																								C
JLQ1	E																								C
AUQ1	E																								C
SPQ1	E																								C
OCQ1	E																								C
NVQ1	E																								C
DCQ1	E																								C
JATR1	L																								
FBTR1	L																								
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AUTR1	L																								
SPTR1	L																								
OCTR1	L																								
NVTR1	L																								
DCTR1	L																								
ALFTR1	L																								
BGTR1	L																								

		JLSTOR20	AUSTOR20	SPSTOR20	OCSTOR20	NVSTOR20	DCSTOR20	JASWW20	FBSWW20	MRSWW20	APSWW20	MYSWW20	JNSWW20	JLSWW20	AUSWW20	SPSWW20	OCSWW20	NVSWW20	DCSWW20	ALFSEL20	BGSEL20	WHTSEL20	CAPTA20	NRTA20	B
NTRET1	L																								
LANDA2	L																								B
LANDB2	L																								B
LANDC2	L																								B
LABOR2	L																								D
OPCAP2	L																								
NIT2	L																								
PHOS2	L																								
JAIR2	L																								
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NVIR2	L																								
DCIR2	L																								
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MRQ2	E																								C
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MYQ2	E																								C
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JLQ2	E																								C
AUQ2	E																								C
SPQ2	E																								C
OCQ2	E																								C
NVQ2	E																								C
DCQ2	E																								C
JATR2	L																								
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JLTR2	L																								
AUTR2	L																								
SPTR2	L																								
OCTR2	L																								
NVTR2	L																								
DCTR2	L																								
ALFTR2	L																								
BGTR2	L																								

APPENDIX E

PICTURE OF FIRST TWO YEARS OF DRYLAND MODEL

		ALFPRD1	BGPRD1	WHTPRD1	BORROW1	LBRBUY1	NBUY1	PBUY1	ALFSEL1	BGSEL1	CAPTA1	NRTA1
OBJ	N	-C	-B	-B	-T	-A	-T	-T	B	B		
LANDA1	L	1										
LANDB1	L		1									
LANDC1	E			1								
LABOR1	L	A	T	T		-1						
OPCAP1	L	B	B	B	-1						1	
NIT1	L		B	B			-1					
PHOS1	L	B	B	B				-1				
ALFTR1	L	-A							1			
BGTR1	L		-A							1		
NTRET1	L	C	B	B	T	A	T	T	-B	-B		1
LANDA2	L											
LANDB2	L											
LANDC2	L											
LABOR2	L											
OPCAP2	L										-1	-U
NIT2	L											
PHOS2	L											
ALFTR2	L											
BGTR2	L											
WHTTR2	L											
NTRET2	L											
LANDA3	L											
LANDB3	L											
LANDC3	L											
LABOR3	L											
OPCAP3	L											
NIT3	L											
PHOS3	L											
ALFTR3	L											
BGTR3	L											
WHTTR3	L											
NTRET3	L											
LANDA4	L											
LANDB4	L											
LANDC4	L											
LABOR4	L											
OPCAP4	L											
NIT4	L											
PHOS4	L											
ALFTR4	L											
BGTR4	L											
WHTTR4	L											
NTRET4	L											
LANDA5	L											
LANDB5	L											

	ALFPRD2	BGPRD2	WHTPRD2	BORROW2	LBRBUY2	NBUY2	PBUY2	ALFSEL2	BGSEL2	WHTSEL2	CAPTA2	NRTA2
OBJ	-C	-B	-B	-T	-A	-T	-T	B	B	A		
LANDA2	1											
LANDB2		1										
LANDC2			1									
LABOR2	A	T	T		-1							
OPCAP2	B	B	B	-1							1	
NIT2		B	B			-1						
PHOS2	B	B	B				-1					
ALFTR2	-A							1				
BGTR2		-A							1			
WHTTR2			-B							1		
NTRET2	C	B	B	T	A	T	T	-B	-B	-A		1
OPCAP3											-1	-U

	ALFPRD3	BGPRD3	WHTPRD3	BORROW3	LBRBUY3	NBUY3	PBUY3	ALFSEL3	BGSEL3	WHTSEL3	CAPTA3	NRTA3
OBJ	-C	-B	-B	-T	-A	-T	-T	B	B	A		
LANDA3	1											
LANDB3		1										
LANDC3			1									
LABOR3	A	T	T		-1							
OPCAP3	B	B	B	-1							1	
NIT3		B	B			-1						
PHOS3	B	B	B				-1					
ALFTR3	-A							1				
BGTR3		-A							1			
WHTTR3			-B							1		
NTRET3	C	B	B	T	A	T	T	-B	-B	-A		1
OPCAP4											-1	-U

	ALFPRD4	BGPRD4	WHTPRD4	BORROW4	LBRBUY4	NBUY4	PBUY4	ALFSEL4	BGSEL4	WHTSEL4	CAPTA4	NRTA4
OBJ	-C	-B	-B	-T	-A	-T	-T	B	B	A		
LANDA4	1											
LANDB4		1										
LANDC4			1									
LABOR4	A	T	T		-1							
OPCAP4	B	B	B	-1							1	
NIT4		B	B			-1						
PHOS4	B	B	B				-1					
ALFTR4	-A							1				
BGTR4		-A							1			
WHTTR4			-B							1		
NTRET4	C	B	B	T	A	T	T	-B	-B	-A		1

	ALFPRD5	BGPRD5	WHTPRD5	BORROW5	LBRBUY5	NBUY5	PBUY5	ALFSEL5
OBJ	-C	-B	-B	-T	-A	-T	-T	B
LANDA5	1							
LANDB5		1						

		NBUY19	PBUY19	ALFSEL19	BGSEL19	WHTSEL19	CAPTA19	NRTA19	ALFPRD20	BGPRD20	WHTPRD20	BORROW20	LBRBUY20	NBUY20	PBUY20	ALFSEL20	BGSEL20	WHTSEL20	CAPTA20	NRTA20	B
OBJ	N	-U	-T	B	B	A			-B	-B	-B	-U	-A	-U	-U	B	B	A			
LANDA1	L																				B
LANDB1	L																				B
LANDC1	E																				B
LABOR1	L																				D
OPCAP1	L																				E
NIT1	L																				
PHOS1	L																				
ALFTR1	L																				
BGTR1	L																				
NTRET1	L																				
LANDA2	L																				B
LANDB2	L																				B
LANDC2	L																				B
LABOR2	L																				D
OPCAP2	L																				
NIT2	L																				
PHOS2	L																				
ALFTR2	L																				
BGTR2	L																				
WHTTR2	L																				
NTRET2	L																				
LANDA3	L																				B
LANDB3	L																				B
LANDC3	L																				B
LABOR3	L																				D
OPCAP3	L																				
NIT3	L																				
PHOS3	L																				
ALFTR3	L																				
BGTR3	L																				
WHTTR3	L																				
NTRET3	L																				
LANDA4	L																				B
LANDB4	L																				B
LANDC4	L																				B
LABOR4	L																				D
OPCAP4	L																				
NIT4	L																				
PHOS4	L																				
ALFTR4	L																				
BGTR4	L																				
WHTTR4	L																				
NTRET4	L																				
LANDA5	L																				B
LANDB5	L																				B

APPENDIX F

MACHINERY COMPLEMENT OF IRRIGATION AND DRYLAND MODELS

MACHINERY COMPLEMENT OF IRRIGATION MODEL,
1984 OKLAHOMA CONDITIONS

	Width (Ft.)	Speed (MPH)	Field Efficiency	HP	Initial List Price
Tractor	--	4.5	0.88	80	$24,500
Tractor	--	4.5	0.88	125	38,300
Pickup Truck	--	20.0	0.88	--	8,500
Offset Disk	18.0	4.8	0.83	--	7,800
Sweep	14.0	4.1	0.76	--	5,500
Chisel	20.0	4.0	0.80	--	8,500
Spike Harrow	20.0	5.3	0.70	--	1,225
Rotary Hoe	20.0	5.0	0.76	--	4,000
Drill	13.0	4.5	0.72	--	4,000
Drill	13.0	4.5	0.72	--	4,000
Planter	20.0	5.0	0.67	--	7,800
Sprayer	36.0	5.0	0.80	--	4,200
Stalk Shredder	13.3	4.8	0.81	--	5,500
PTO Mower Conditioner	12.0	4.3	0.77	--	11,000
PTO Baler	20.0	3.0	0.67	--	8,000
PTO Balewagon	14.0	5.0	0.40	--	14,000

Source: Oklahoma State University Enterprise Budgets

MACHINERY COMPLEMENT OF DRYLAND MODEL,
1984 OKLAHOMA CONDITIONS

	Width (Ft.)	Speed (MPH)	Field Efficiency	HP	Initial List Price
Tractor	--	4.5	0.88	80	$24,500
Tractor	--	4.5	0.88	125	38,300
Pickup Truck	--	20.0	0.88	--	8,500
Self-Propelled Swather	16.0	5.4	0.77	75	28,500
Moldboard Plow	7.5	4.5	0.90	--	11,500
Offset Disk	18.0	4.8	0.83	--	7,800
Sweep	24.0	4.5	0.76	--	9,000
Springtooth	24.0	5.3	0.70	--	5,000
Field Cultivator	20.0	3.8	0.76	--	4,600
Drill	13.3	4.0	0.72	--	8,700
Rod Weeder	20.0	4.8	0.83	--	4,900
Hoe Drill	13.0	4.5	0.72	--	5,900
Hoe Drill	13.0	4.5	0.72	--	5,900
Planter	20.0	5.0	0.67	--	7,800
Sprayer	36.0	5.0	0.80	--	4,200
Hay Baler	5.0	3.0	0.67	--	8,000

Source: Oklahoma State University Enterprise Budgets

VITA

Donald Edward Thomason, Jr.

Candidate for the Degree of

Master of Science

Thesis: ECONOMIC AND ENVIRONMENTAL IMPACTS OF USING MUNICIPAL SEWAGE EFFLUENT AS IRRIGATION WATER FOR AGRICULTURAL PRODUCTION IN OKLAHOMA

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Bessemer, Alabama, September 7, 1958, the son of Don and June Thomason

Education: Graduate from Butler County High School, Morgantown, Kentucky, in May, 1976; received the Bachelor of Science Degree in Production Agriculture from the University of Kentucky in May, 1980; completed requirements for the Master of Science Degree at Oklahoma State University in May, 1985.

Professional Experience: Research Assistant, Department of Agricultural Economics, Oklahoma State University, September 1982 to November, 1984; member of the American Agricultural Economics Association, the Southern Agricultural Economics Association, the Western Agricultural Economics Association, and the Oklahoma Agricultural Economics Association.